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CALL ALERT RECEIVER SYSTEM

Final Report
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PREPARED FOR:

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PREPARED BY:

G. V. Kopcsay and P. J. Meier
Advanced Microwave Systems Department
Applied Electronics Division

Cert. #200335

541056

J. Ayoub
Code 5439

AIL a division of CUTLER-HAMMER

DEER PARK, LONG ISLAND, NEW YORK 11729

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FOREWORD

This is the final report describing the mast mounted CALL ALERT receiver which was prepared under Contract N00173-75-C-0470 by AIL, a division of Cutler-Hammer, Melville, New York 11746. The work was sponsored by the Naval Research Laboratory, Washington, D.C. Technical supervision of this program was under the cognizance of J. Ayoub of NRL whose direction and encouragement is gratefully acknowledged.

This program was performed at AIL in the Advanced Microwave Systems Department under the supervision of J.J. Whelehan, Jr., S. Becker and M. Balfour. Technical assistance was provided by W.C. Reinheimer, J.J. Hamilton, H.E. Becker, R. Gibbs and L. Hernandez.

This report covers the period from May 1975 to April 1976.

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Section I

INTRODUCTION

This is the final technical report describing the design and development of a low-cost shipboard Mast Mounted CALL ALERT (MMCA) receiver system. Three prototype MMCA systems were built to demonstrate the feasibility of the design. These engineering models were configured so that they can be tested aboard ship to demonstrate the practical utility of the MMCA system.

The equipment developed on this program depended heavily upon AIL's patented fin-line[1] millimeter wave transmission techniques. By utilizing its fin-line techniques, AIL's goal in the proposed program was to evolve a design that will ultimately minimize the cost of the system to the Navy. The proposed program was dedicated to this goal by planning, specifying and designing for low cost from the inception of the project.

The MMCA system is intended to be used aboard Navy ships as a means of alerting appropriate personnel of the existence of an incoming signal in the K_a frequency band and of the approximate direction of its origin. The key components of this system are:

a. A narrow-beam horn antenna, rotating in the azimuth plane.

b. A K_a-band receiver having the appropriate sensitivity and noise figure.

c. A visual and aural display indicating the presence and direction of origin of the received signal.

The proposed system was designed in two basic parts:

a. The mast-mounted equipment designed to withstand shipboard environments.

b. The display and power supply section, located remote from the mast-mounted equipment in a weather resistant housing.

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[1] U.S. Patent No. 3,825,863. Since the US Government holds a Confirmatory License on this patent, there are no restrictions in applying these techniques in the present application.

All of the performance design goals, which are detailed in Section II, have been achieved for the MMCA receiver system. In addition, the production cost of a complete receiver system of the present configuration is estimated to be $8,900 each in quantity of 100 systems.

In the following sections the design of the MMCA receiver system is described in detail. Design and test data for various subcomponents of the system are also given. The prototype systems are described along with data on their overall performance. Finally, operation and maintenance instructions and schematic diagrams are given in the Appendices.

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Section II

SYSTEM DESIGN

2.1 PERFORMANCE SPECIFICATIONS

The MMCA receiver developed on this program is designed to detect an RF signal originating from a transmitter (supplied by NRL) having the following characteristics:

a. Frequency: Between 36.7 and 37.2 GHz

b. Emission: CW (RF carrier only)

c. Transmitter power at antenna input: 100 mW

d. Transmitter antenna gain: 30 dB

e. Transmitter antenna polarization: linear, 45° to horizon

The MMCA receiver is designed to have the following electrical characteristics:

a. Sensitivity: Receive a signal from the specified transmitter at a range of 10 nautical miles (nm) during conditions of light rainfall (estimated path loss -157 dBm)

b. MMCA antenna: Mechanically rotating horn

c. Antenna beamwidths: Azimuth 5° (3 dB down)
Elevation 20° (3 dB down)

d. Antenna gain: 21 dB (for linearly polarized input signal)

e. Antenna polarization: Circular polarization

f. Antenna rotation: 30 rpm

g. Display indication: Audible alarm and 16 LED lamps representing 22.5 degree sectors of the compass rose

The MMCA receiver is designed to have the following physical characteristics:

a. Configuration:

1. Mast-mounted receiver assembly

2. Remote alarm/display and power supply assembly

b. Environment (Design Goal)

1. Exposed shipboard conditions are as per MIL-E-16400 requirements for Class 2 temperature, humidity, salt-spray, water-spray, wind, icing and precipitation

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2. All equipment is configured to survive sea trials, but no formal environmental test program was conducted.

2.2 SYSTEM CONFIGURATION

A block diagram of the system which was evolved to meet the above requirements is shown in Figure 1.

The RF input (an unmodulated millimeter-wavelength carrier) enters the fin-line subassembly from the circularly polarized antenna. The RF is first chopped by a fin-line PIN modulator which addes the audio information that will be detected in the back end. The input next passes through the RF bandpass filter, which rejects unwanted signals such as those at the local oscillator (LO) and image frequencies. The signal is then combined with the LO signal in the mixer to provide the desired 2 GHz output. The LO signal enters the fin-line subassembly and passes through a fixed pad that serves two functions:

1. The LO power (typically 50 mW) is reduced to a level (approximately 4 mW at the mixer) and optimizes the overall noise figure.
2. The out-of-band mismatch introduced by the LO bandpass filter is reduced without a costly ferrite isolator.

The LO signal enters the mixer through the LO bandpass filter which provides the desired reactive termination at the signal and image frequencies.

A Gunn diode oscillator (GDO) operating at 35 GHz is used as the LO. The GDO is temperature stabilized with a heater operated by a proportional temperature controller. This is required to stabilize the output power and frequency of the GDO.

A 2-GHz transistorized IF amplifier then amplifies the signal prior to first detection by a simple AM detector.

The 1-kHz audio information is then extracted by a narrowband synchronous detector (e.g., Signetics 567 Phase-Locked-Loop (PLL), available in integrated circuit (IC) form). Its center frequency is tuned to the 1-kHz output of the AM first detector which will be present only when an incoming call is received by the antenna. Since the

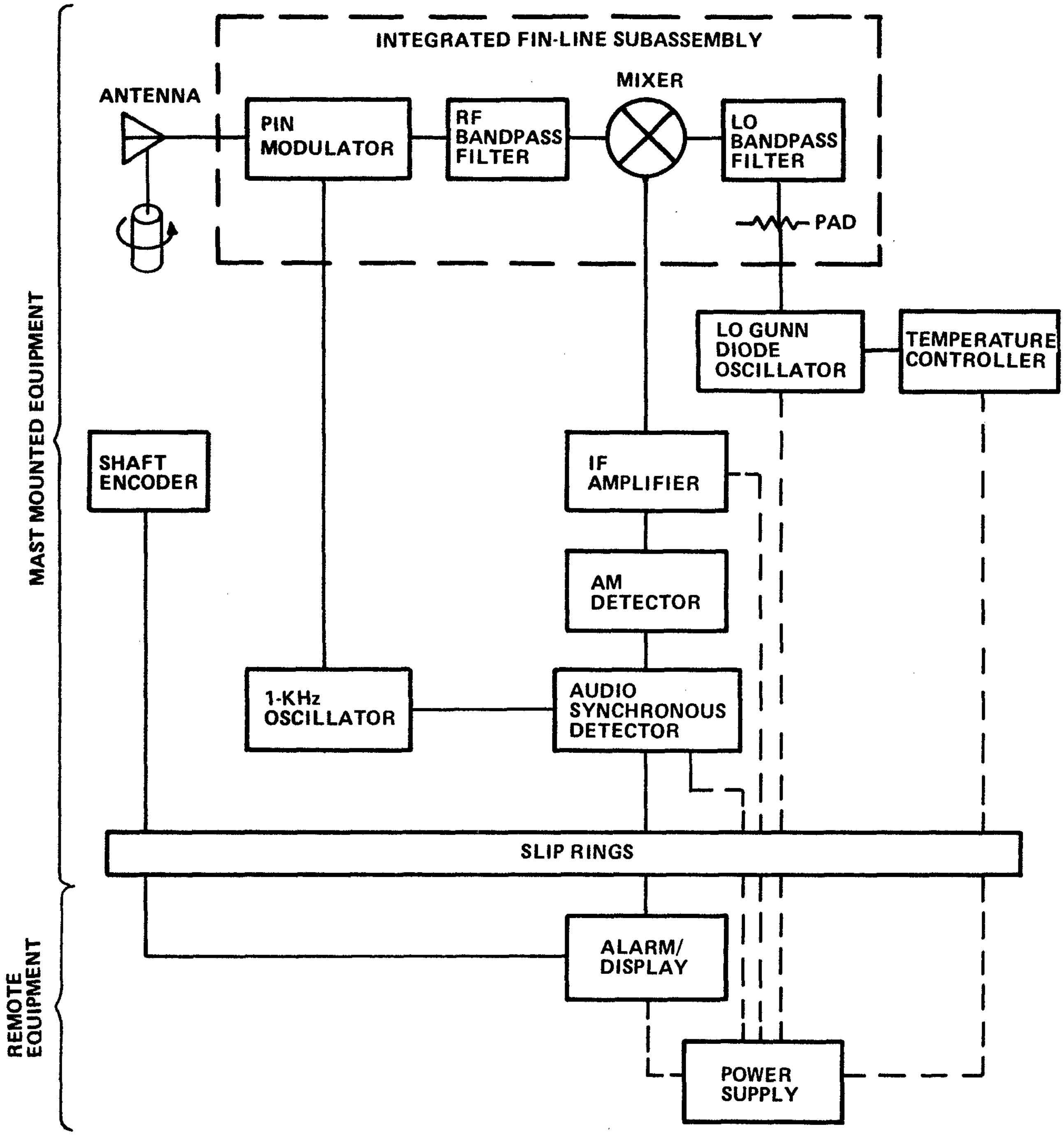


Figure 1. Mast Mounted CALL ALERT Receiver System, Block Diagram

antenna beamwidth is 5 degrees, this signal will be present for only 28 milliseconds (ms) of the two-second sweep time for any one call. The presence of a synchronous detector output will be fed to the input of each of 16 opto-electronic switches located in the non-rotating base of the mast-mounted receiver assembly. Each opto-electronic switch consists of an LED/photo transistor pair. When an input signal is present, the LED segments in all of the 16 optical switches are energized. A mechanical shutter allows only the photo transistor that corresponds to the antenna orientation to saturate. This results in a signal, transmitted through an interconnecting cable to the alarm/display, which drives one of 16 timer circuits that, in turn, provide current drive for the display LED's.

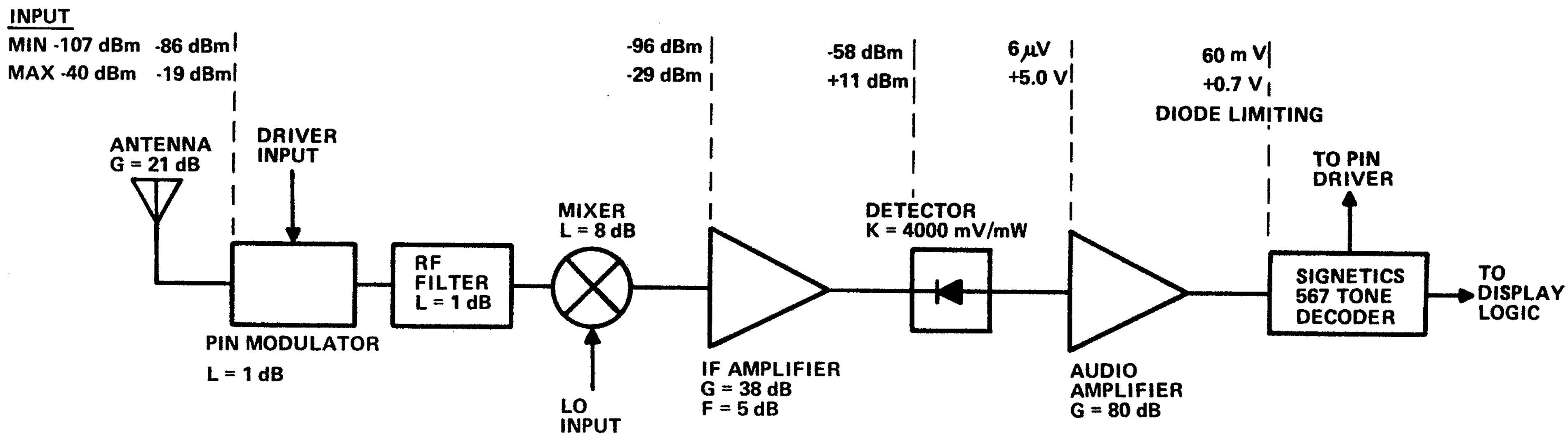
The visual display consists of 16 LED's arranged in a circle, each representing a 22.5-degree sector of the compass rose. In addition, the activation of any of the display LED's will energize an audio alarm (sonalert buzzer).

The timers are a necessary intermediate circuit function to maintain an LED and aural output for greater than the 28-ms duration it takes the antenna to sweep by a calling signal. The timers are set for a one-second duration which is half the time for one antenna revolution (two seconds at 30 rpm). This results in a flashing (one second on , one second off) display.

It should be noted from Figure 1 that the system is configured so that the slip-rings conduct only dc voltages and audio signals. This minimizes the expense and complexity that would otherwise be introduced by RF rotary joints.

2.3 SYSTEM GAIN-NOISE BUDGET

In order to determine that the proposed receiver configuration would meet the system sensitivity requirements, the gain and noise budget shown in Figure 2 was prepared. The assumed values of component specifications were chosen to provide acceptable receiver performance while allowing the development of low-cost fin-line designs. Specifications for the individual components are discussed in Section III.



Transmit Power	:	+20 dBm
Transmit Antenna Gain	:	30 dB
Path Loss (Maximum)	:	-157 dB (10 mm plus light rain)
Power at Receiver (Minimum)	:	-107 dB
Receive Antenna Gain	:	21 dB
Receiver Input (Minimum)	:	-86 dB
Path Loss (Minimum)	:	- 90 dB (20 meters)
Power at Receiver (Maximum)	:	-40 dBm
Receiver Input (Maximum)	:	-19 dBm

Receiver Noise Figure : 15 dB (Maximum)

Noise Power Input

$$N = KTBF$$

$$B = \sqrt{2B_{IF} \times B_{AF}} = 0.316 \text{ MHz}$$

$$N = \frac{114 \text{ dBm}}{\text{MHz}} + 15 = -104 \text{ dBm}$$

Input signal-to-noise ratio (S/N)

$$S/N = 18 \text{ dB}$$

Figure 2. MMCA Receiver Power/Sensitivity Budget

First, it is necessary to determine the signal level that will appear at the input to the integrated fin-line module. The path loss due to propagation in free-space is given by:

$$L_p = \left[\frac{\lambda}{4\pi R}\right]^2 \tag{1}$$

which for R = 10 nm is:

$$L_p = -150 \text{ dB}$$

If one accounts for typical light rainfall conditions, then an additional loss is added so that the total path loss is:

$$L_t = -157 \text{ dB}$$

The signal carrier available at the receiver terminals can be evaluated using

$$C = \left[\frac{\lambda}{4\pi R}\right]^2 P_t \; G_t \; G_r \tag{2}$$

where:

P_t = transmitter power
G_t = transmit antenna gain
G_r = receive antenna gain

Then,

$$C_{dBm} = (L_t)_{dB} + (P_t)_{dBm} + (G_t)_{dBm} + (G_r)_{dB} \tag{3}$$

yielding,

$$C_{dBm} = -157 + 20 + 30 + 21 = -86 \text{ dBm}$$

available at the input to the fin-line receiver module.

A similar calculation for a range of 20 meters yields a signal power of

$$C_{dBm} = -40 \text{ dBm}$$

available at the input to the fin-line receiver module. This is assumed to be a typical minimum range to verify that there is no component saturation.

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It is now necessary to evaluate the receiver carrier-to-noise ratio, C/N, as referred to the output of the synchronous detector. The normalized Johnson noise of any receiver is

$$(No)_{dB} = kT = -114 \text{ dBm/MHz} \tag{4}$$

for an ambient temperature, T = 300 K. Since the receiver module described above will have a noise figure of 15 dB, the residual normalized noise level of the receiver is then,

$$(N_r)_{dB} = -114 \text{ dBm/MHz} +15 \text{ dB} = -99 \text{ dBm/MHz} \tag{5}$$

To determine the absolute noise level, one must evaluate the equivalent noise bandwidth of the receiver, as referred to the output of the audio detector (synchronous detector). The equivalent noise bandwidth is given by

$$B = \sqrt{B_{IF} \times 2B_{AF}} \tag{6}$$

B_{IF} is the IF bandwidth. The required IF bandwidth is determined by the transmitter frequency band and by the frequency drift of the LO. For this analysis

$$B_{IF} = 500 \text{ MHz} \tag{7}$$

is used. An equivalent narrowband audio bandwidth of

$$B_{AF} = 100 \text{ Hz} \tag{8}$$

is conservatively assumed for the synchronous detector. Thus,

$$B = \sqrt{B_{IF} \times 2B_{AF}} = 0.316 \text{ MHz}$$

The absolute receiver noise level is now determined by substituting the value of B (0.316 MHz) into equation (5) to obtain

$$(N)_{dB} = -99 \text{ dBm/MHz} -5 \text{ dB} = -104 \text{ dBm}$$

In summary, the available carrier signal is shown to be C = -86 dBm, the noise level is N = -104 dBm. Therefore C/N = +18 dB is thus expected. This analysis indicates that adequate margin is available for the reception of the specified transmitter signal.

Section III

COMPONENT DESIGN

3.1 FIN-LINE RF FRONT END

3.1.1 General

As stated in Section I, AIL's choice of transmission media for the components that were developed on this program was dictated by the philosophy of designing for lost cost. To achieve low cost for millimeter wavelength components an IC approach which is amenable to batch processing techniques is most attractive.

As stated by Meier (Ref. 1), increased activity in the spectrum above 30 GHz has recently stirred interest in the development of millimeter IC's. Much of the enthusiasm associated with IC's can be traced to the clear advantages that such circuits provide below 3 GHz, namely reduced size, weight, and cost combined with improved electrical performance, production uniformity, and reliability. However, those who have worked with IC's at centimeter wavelengths (3 to 30 GHz) have encountered some fundamental problems that have limited the utility of such circuits. These problems include the critical tolerances and questionable production uniformity that can occur when miniaturization is carried too far. Although enhanced performance is possible in centimeter IC's through the reduction of parasitics and the elimination of superfluous interfaces, poorer overall performance is also possible. The fundamental microstrip problems, which generally increase in severity as the operating frequency is raised, include radiation loss, spurious coupling, dispersion, and higher-mode propagation. Attempts to integrate a large number of components in a single housing have generally demonstrated the need for "mode barriers" and "box-resonance absorbers." Radiation and related problems can be controlled by choosing progressively thinner substrates as the operating frequency is raised, but this only serves to degrade the Q factor, compound tolerance problems, and restrict the range over which the characteristic impedance can be varied.

Although standard microstrip techniques can be applied to millimeter components (References 2 and 3), the problems listed previously can be expected to become more severe. As the operating frequency is raised and the microstrip dimensions are decreased, a limit will be reached where the strip width is no longer compatible with chip and beam-lead devices. In addition, millimeter IC's must be tailored to requirements that are generally different from those which apply at lower frequencies. For example, the ability to construct a simple transition to waveguide becomes important at millimeter wavelengths where coaxial instrumentation is not practical. Moreover, the miniaturization that proved to be an asset at centimeter wavelengths can become a liability in millimeter applications. Designers of millimeter equipment have historically selected quasi-optical approaches to increase the physical size of components and thereby ease tolerance problems and improve performance (Ref. 4). Thus, the ideal transmission line for millimeter IC's is one that avoids miniaturization and yet offers the potential for low-cost production through batch processing techniques. Integrated fin-line (References 1, 5, and 6) is such a transmission line.

In an integrated fin-line structure, metal fins are printed on a dielectric substrate that bridges the broad walls of a rectangular waveguide. This adaptation of ridge-loaded waveguide permits circuit elements to be photoetched by low-cost batch techniques. The dimensions of practical fin-line circuits remain compatible with chip and beam-lead devices throughout the millimeter spectrum, thereby offering great potential for the construction of active and passive hybrid integrated circuits.

In addition to serving as the bonding areas for hybrid devices, the printed fins increase the separation between the first two modes of propagation thereby providing a wider useful bandwidth than obtained with conventional waveguide. Owing to the similarity between integrated fin-line and conventional ridged waveguide, considerable design information (References 7 and 8) is available. For thin substrates of moderate permittivity, the dielectric has a minor effect (Ref. 9) and the single-mode bandwidth and attenuation of integrated fin-line can be estimated from existing data (References 8, 9, and 10). Such estimates lead to the conclusion that integrated fin-line can provide bandwidths in excess of an octave with less attenuation than is obtained with microstrip. Larger single-mode bandwidths are feasible at the expense of attenuation.

From the block diagram in Figure 1 we see that the millimeter wave receiver components required for this system are as follows:

- Fin-line PIN Modulator
- Fin-line RF Bandpass Filter
- Fin-line LO Bandpass Filter
- Fin-line Mixer Mount
- Fin-line Fixed Absorbtive Attenuator

Design goals for the performance of each of these elements were determined from the system specifications. Upon successfully completing the development of each of these components, an integrated receiver subassembly was developed that incorporates each of the functions into a single package. This RF receiver subassembly is the key element in AIL's millimeter CALL ALERT system.

The tasks which were required to complete this effort are described in detail in the following subsections.

3.1.2 Fin-Line PIN Modulator

The design goals for a PIN modulator suitable for impressing the required modulation on a received RF signal are as follows:

• Insertion Loss:	1 dB (at zero bias)
• Maximum Attenuation:	18 dB
• Maximum VSWR:	2.0
• Center Frequency:	37.0 GHz
• Bandwidth:	2 GHz

The modulator design was directly scaled from a previous development at a slightly lower frequency (Ref. 11). Attenuation versus bias current which was measured for the PIN attenuator design is shown in Figure 3. With a reverse bias voltage of -12 V on the PIN diodes (no current) the insertion loss dropped to 0.9 dB.

3.1.3 Fin-Line RF Bandpass Filter

To provide image and LO rejection, the input port of the mixer incorporates a bandpass filter. Design goals for this filter were set as follows:

- Center Frequency: 37 GHz
- Bandwidth (3 dB): 1.8 GHz
- Insertion Loss: 0.8 dB
- LO Rejection: 12 dB
- Image Rejection: 18 dB

The first step in designing the desired filter was to evaluate the susceptance of shunt strips which are suitable for use as filter elements. The result of these measurements using a transmission technique is shown in Figure 4.

A two-pole equal-element filter was then designed resulting in the breadboard performance shown in Figure 5. This design was slightly shifted to center the passband at 37 GHz and was then used in the final integrated receiver subassembly.

3.1.4 Fin-Line LO Bandpass Filter

An LO filter is required to provide a reactive termination at the signal and image frequencies. Design goals for this filter are:

- Center Frequency: 35 GHz
- Bandwidth (3 dB): 1 GHz
- Insertion Loss: 1 dB
- Image Rejection: 20 dB
- Signal Rejection: 20 dB

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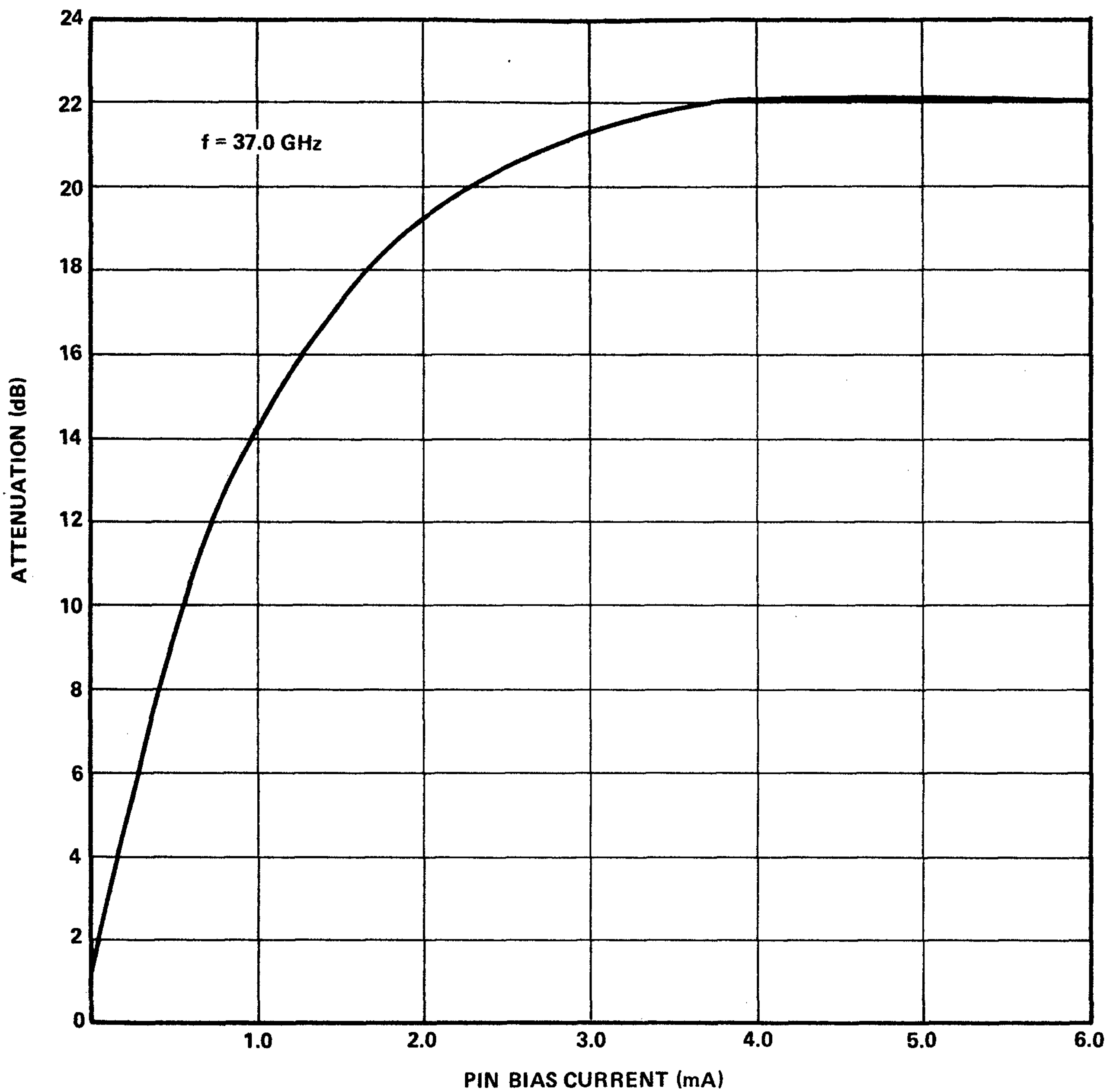

Figure 3. Attenuation Versus Bias for Fin-Line PIN Attenuator

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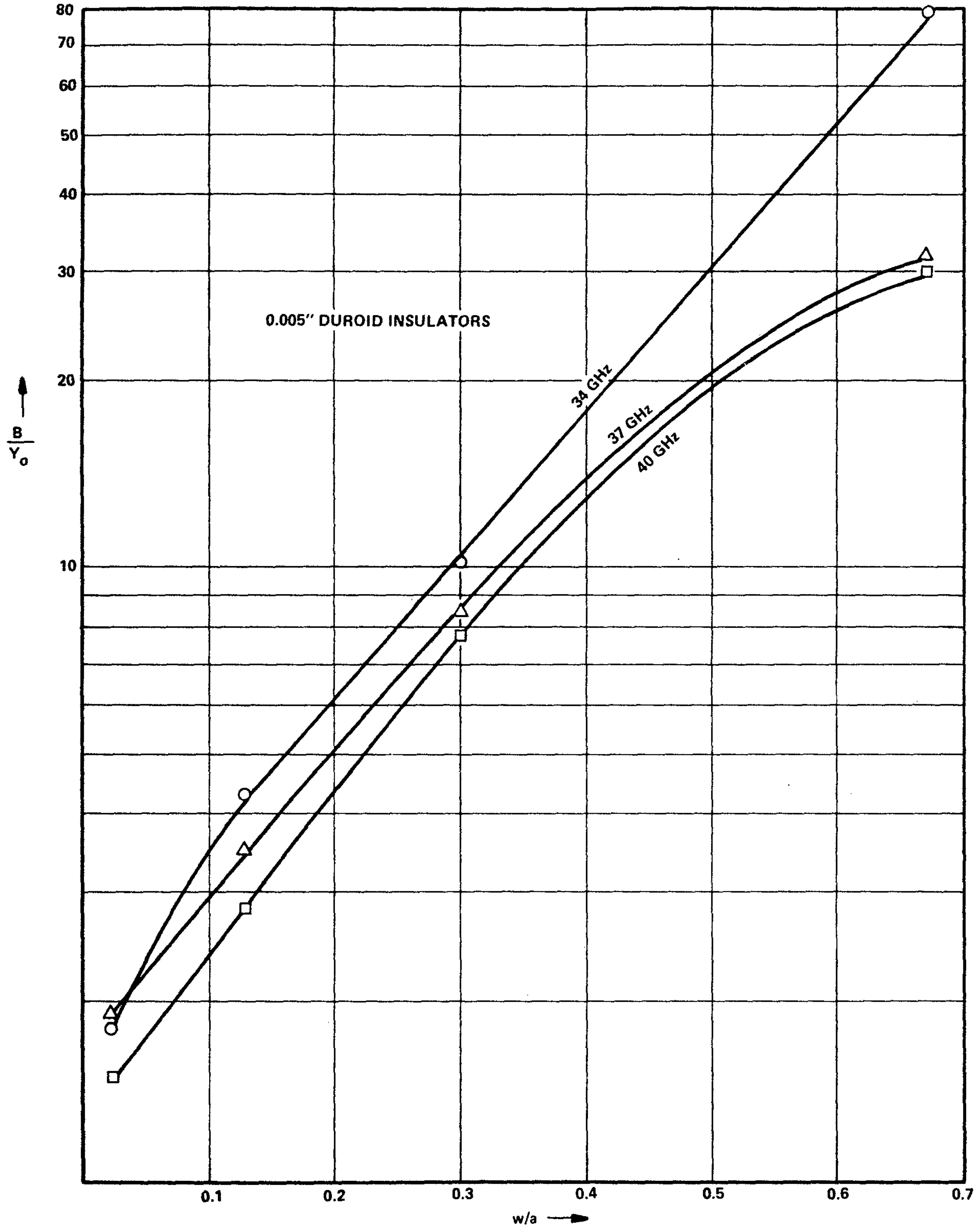

Figure 4. Shunt Susceptance (B/Y) versus Strip Width (w/a) for Insulated Strip on One Side 0.0.010-inch Duriod

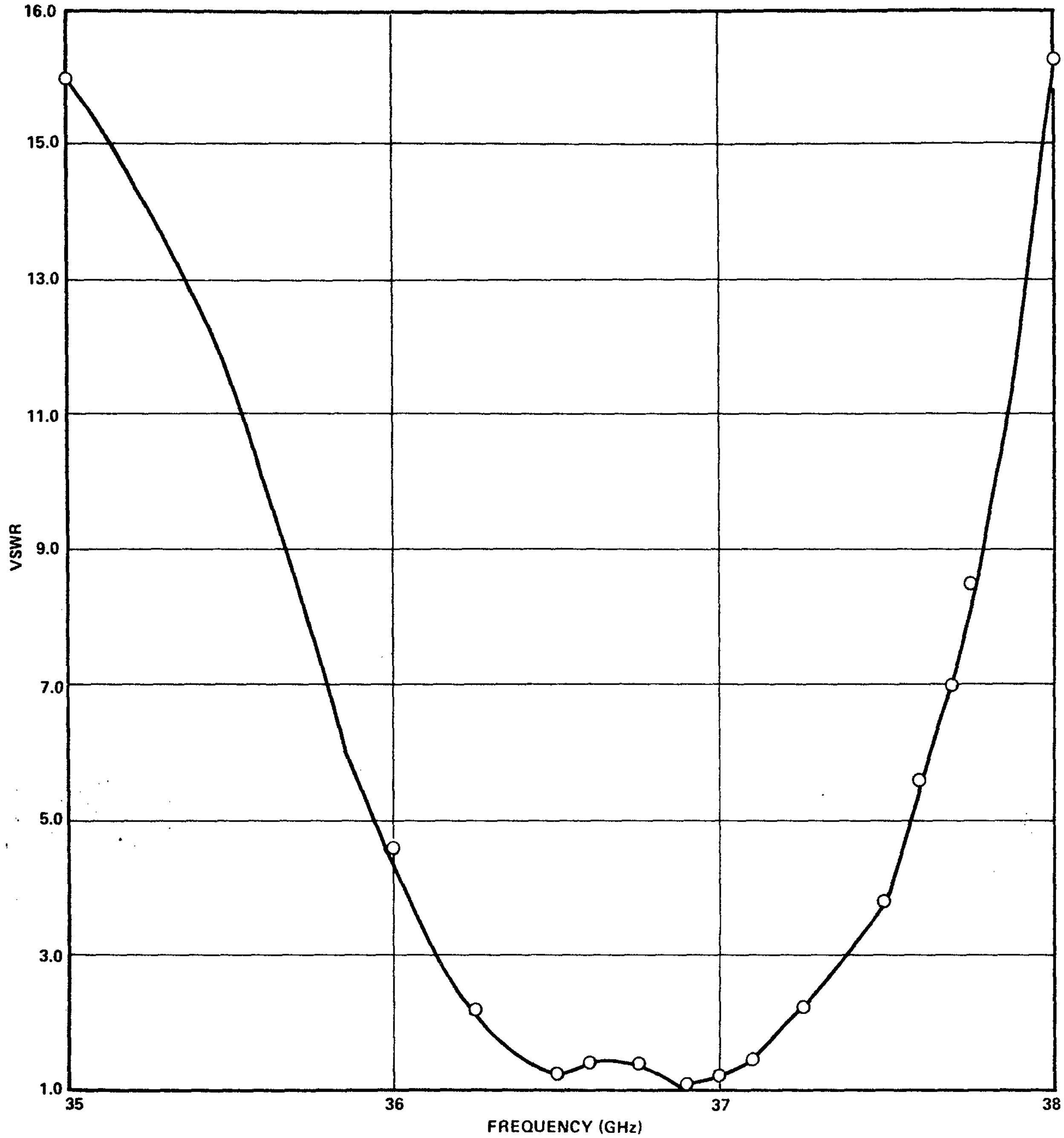

Figure 5. Measured Performance of RF Bandpass Filter

Following a design procedure similar to that already described for the RF filter, a two-pole, equal-element filter was constructed and produced the results shown in Figure 6. This filter design was then incorporated in the final integrated receiver subassembly.

3.1.5 Fin-Line Mixer Mount

Design goals for a mounting structure for the diode which forms the mixer element are as follows:

• Signal Frequency:	36.7 to 37.2 GHz
• LO Frequency:	35 GHz
• LO Power:	2 mW
• Signal VSWR:	1.5
• LO VSWR:	2.0
• IF Output	1.7 to 2.2 GHz

The mixer design consists of a single beam-lead Schottky barrier diode which is coupled to the fin-line by a printed monopole. The dimensions of the monopole were chosen to optimize impedance match at both the signal and the LO frequencies. The starting point for the present design was based upon previous work at a lower frequency (Ref. 11).

The VSWR performance of the final breadboard mixer diode mount is summarized in Figure 7. This design was used to realize the mixer in the final prototype receiver subassemblies.

3.1.6 Fin-Line Fixed Absorbtive Attenuator

Design goals for the fixed attenuator which is used at the mixer LO input are as follows:

• Attenuation:	13 dB
• VSWR:	1.2
• Center Frequency:	35 GHz
• Bandwidth:	2 GHz

The LO pad was fabricated from a section of resistance card (Solitron film card, 750 ohms per square). The length of the card was chosen to achieve the required attenuation. Notched step transitions into the card were chosen to optimize the impedance

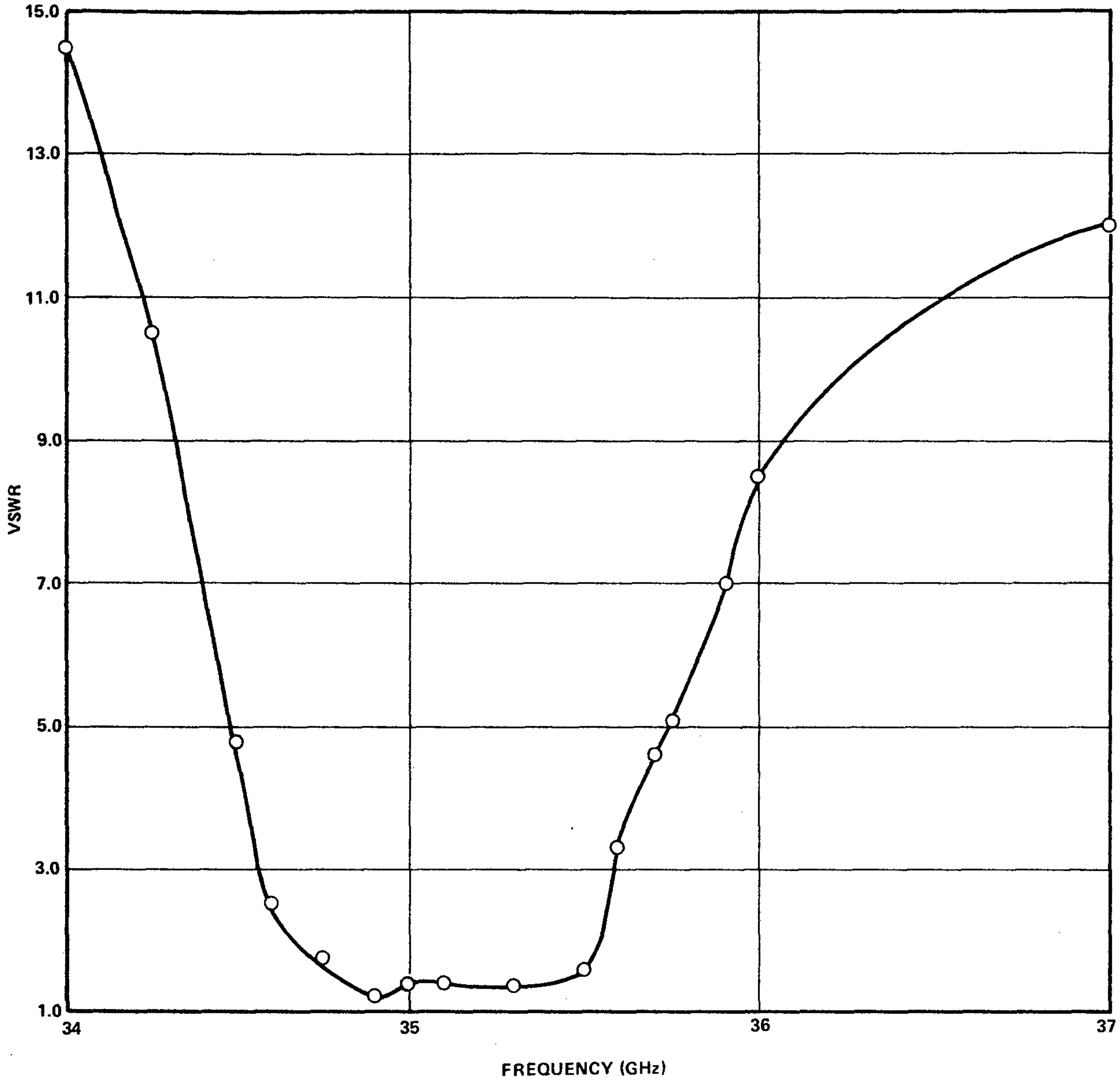

Figure 6. Measured Performance of LO Bandpass Filter

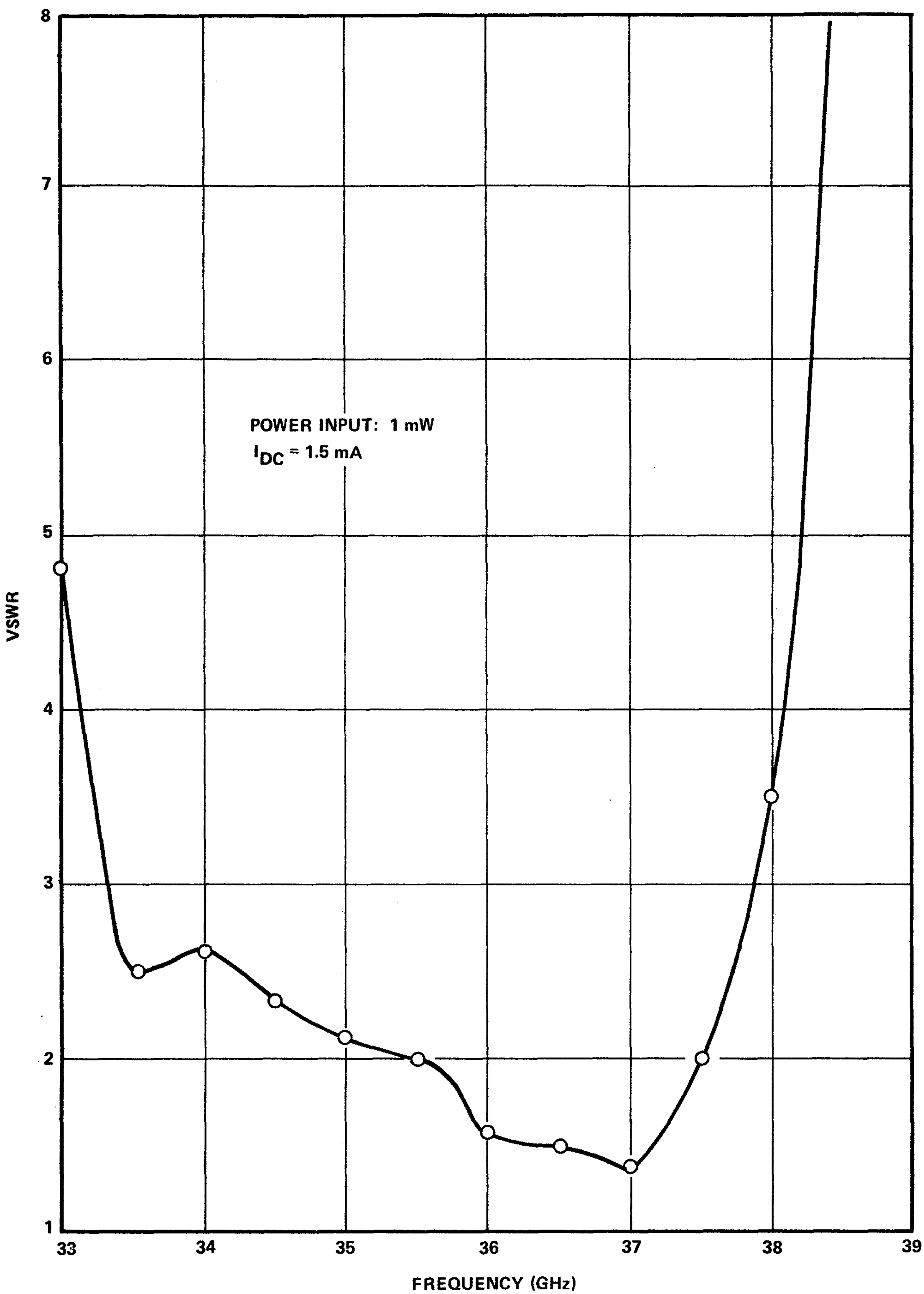

Figure 7. VSWR of Breadboard Mixer Diode Mount

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match. The resistive card was mounted across the broad walls of the rectangular waveguide in place of a section of the fin-line substrate. Three pads were fabricated for the prototype systems. The measured attenuation for these units varied from 13.3 to 14.2 dB. The VSWR of these attenuators varied from 1.10 to 1.16. This performance was suitable for incorporation into the final prototype fin-line receiver subassemblies.

3.1.7 Integrated Fin-Line Receiver Module

The component designs described in the previous sections have been integrated to form the RF receiver subassembly shown in Figure 8. The fin-line circuit is constructed with transitions to WR22 waveguide at the RF input and LO ports. PIN bias is injected through one SMA connector. The IF output and mixer bias are transmitted through the second SMA connector.

The construction of the fin-line module is similar to components previously described in References 11 and 12. The fin-line board is mounted in a split housing. However, for this program, the housing was redesigned to allow positive metallic contact between halves while providing strain relieved location of the fin-line substrate. This was done in an effort to ensure reliable operation in a rugged shipboard environment.

The substrate itself is 0.010-inch thick duroid metallized with copper which is etched to the desired circuit pattern using standard photolithographic techniques. The fins are insulated from the housing at dc by a kapton dielectric gasket, but is grounded at RF by choosing the thickness of the waveguide walls to be $\lambda/4$ in the dielectric medium. DC bias and IF output are transmitted through stripline chokes printed on the substrate.

Three fin-line receiver modules were fabricated for the prototype MMCA systems. The measured performance of these subassemblies is summarized as follows. Conversion loss data are shown in Table I. RF input VSWR is presented in Table II. The measured noise figure for one of the subassemblies (including the IF noise contribution of 5 dB) is plotted in Figure 9.

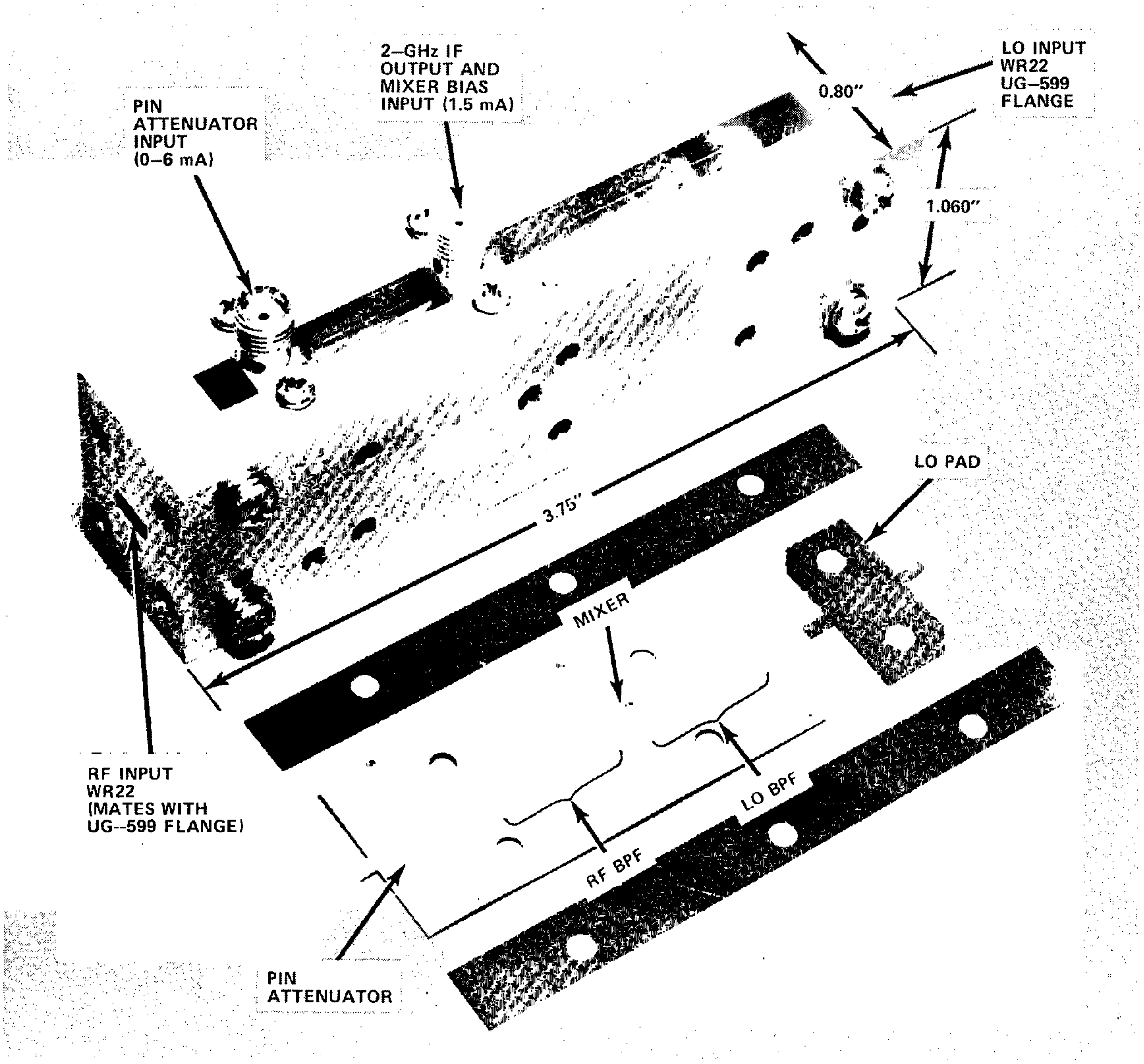

Figure 8. Fin-Line RF Receiver Module

TABLE I

CONVERSION LOSS OF PROTOTYPE FIN-LINE RECEIVER MODULES
(Zero-Volt PIN Diode Bias)

	f_{RF} (GHz)		
Unit	36.7	37.0	37.2
S/N 1	11.6 dB	13.0 dB	14.3 dB
S/N 2	11.5 dB	14.0 dB	12.2 dB
S/N 3	10.8 dB	12.6 dB	11.3 dB

TABLE II

RF INPUT VSWR OF PROTOTYPE FIN-LINE RECEIVER MODULES

f_{RF} (GHz)	Serial No. 001	Serial No. 002	Serial No. 003
36.50	1.10	1.60	2.1
36.75	1.16	1.18	1.37
37.00	1.55	1.37	1.70
37.25	2.8	2.5	2.5
37.50	6.5	4.6	4.3

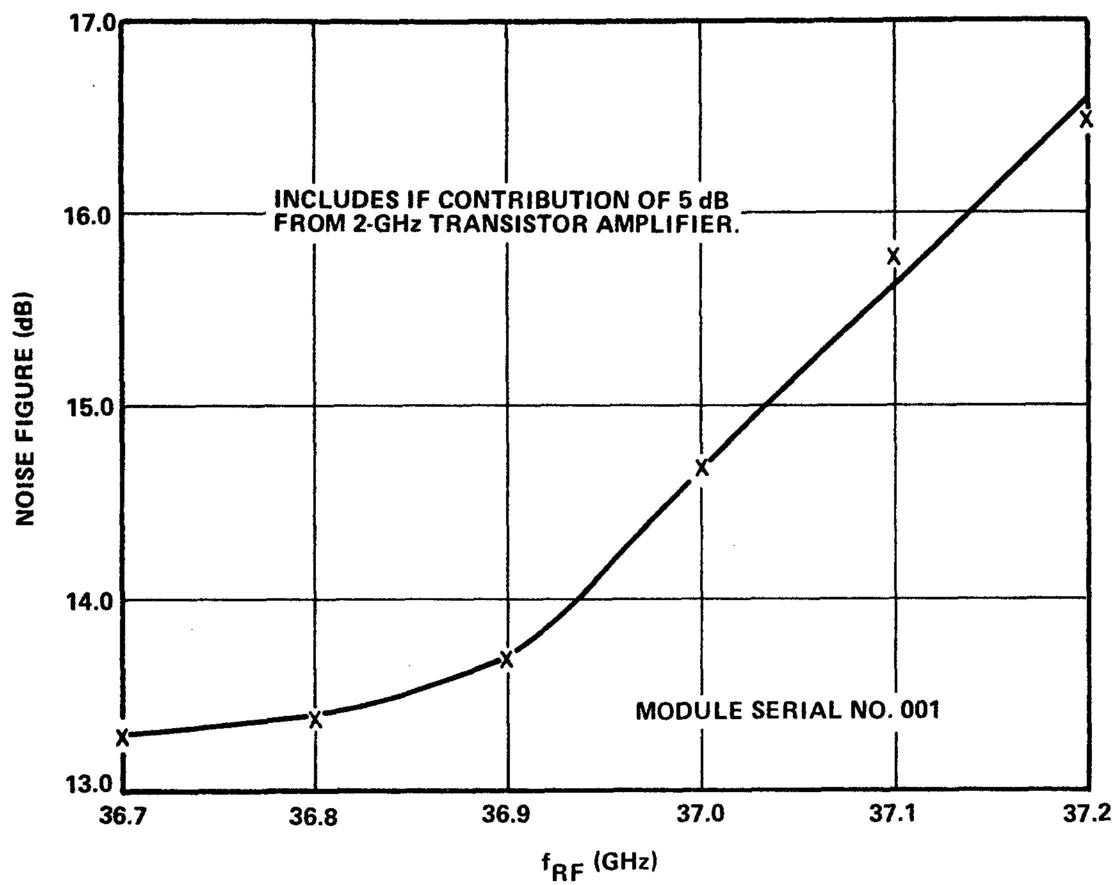

Figure 9. Measured Noise Figure of Fin-Line Receiver Module

The performance summarized above was considered acceptable for use in the prototype MMCA systems. Commercial GDO's were purchased from Microwave Associates for use as LO sources. The LO is mounted directly to the fin-line module LO input flange. The purchased GDO's had the following characteristics:

- Frequency: 35.0 GHz
- Power: 50 mW minimum
- Load VSWR: 1.2 maximum
- Operating Temperature: 0 to 50°C

3.2 ANTENNA

Design goals for the antenna which is utilized in the MMCA system are as follows:

- Frequency: 36.7 to 37.2 GHz
- Gain: 21 dB (for linearly polarized signals)
- Azimuth Beamwidth: 5°
- Elevation Beamwidth: 20°
- VSWR: 1.5
- Polarization: Circular

A pillbox antenna was designed to meet these specifications. The antenna is excited through a probe coupling to a WR22 waveguide which mates with the RF input of the fin-line receiver module. A polarizer plate is used in front of the aperture to provide the circular polarization.

The horn section of the antenna was electroformed using a stainless steel mandril. A photograph of the completed antenna is shown in Figure 10.

The measured performance of the three prototype antennas is as follows:

- VSWR: 1.4 maximum
1.15 typical
- Gain: 23.6 $\pm$ 0.5 dB (circularly polarized)

In addition, antenna patterns were measured on the first unit. In Figures 11 and 12 antenna patterns are presented for the azimuth plane with vertical and horizontal polarizations respectively. In

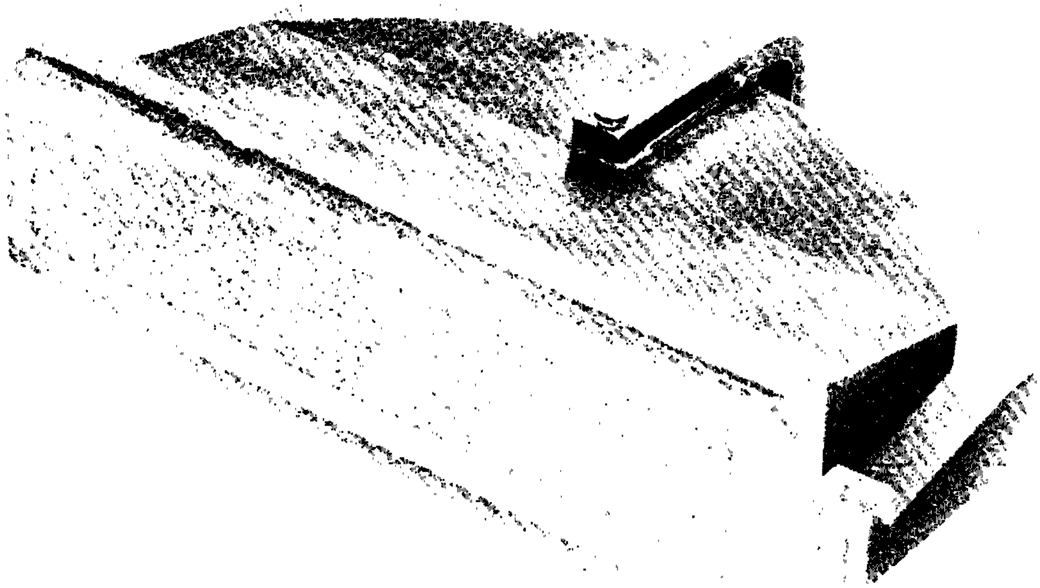

Figure 10. 37-GHz Pillbox Antenna

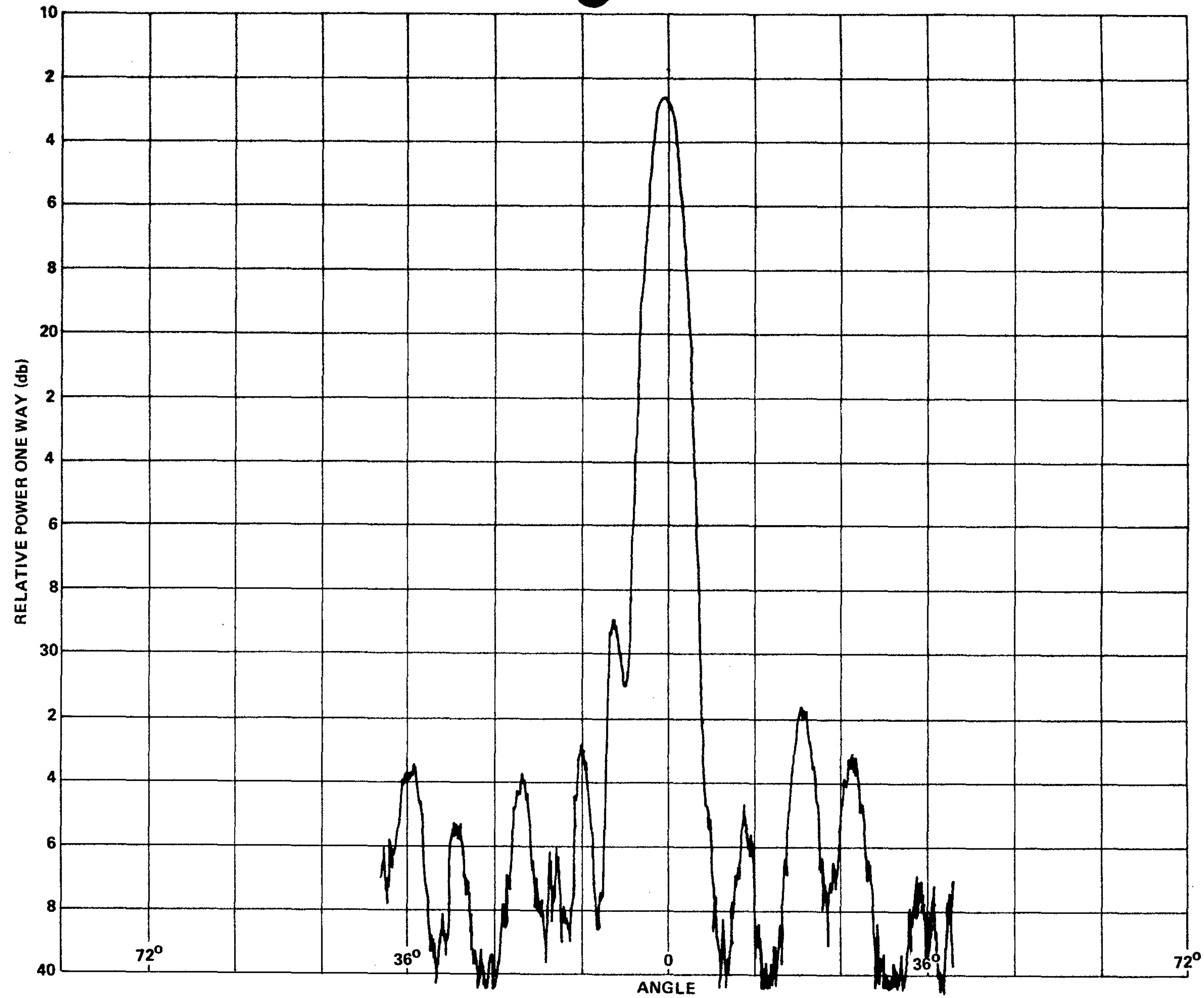

Figure 11. MMCA Antenna Test Pattern, Azimuth Plane, Vertical Polarization

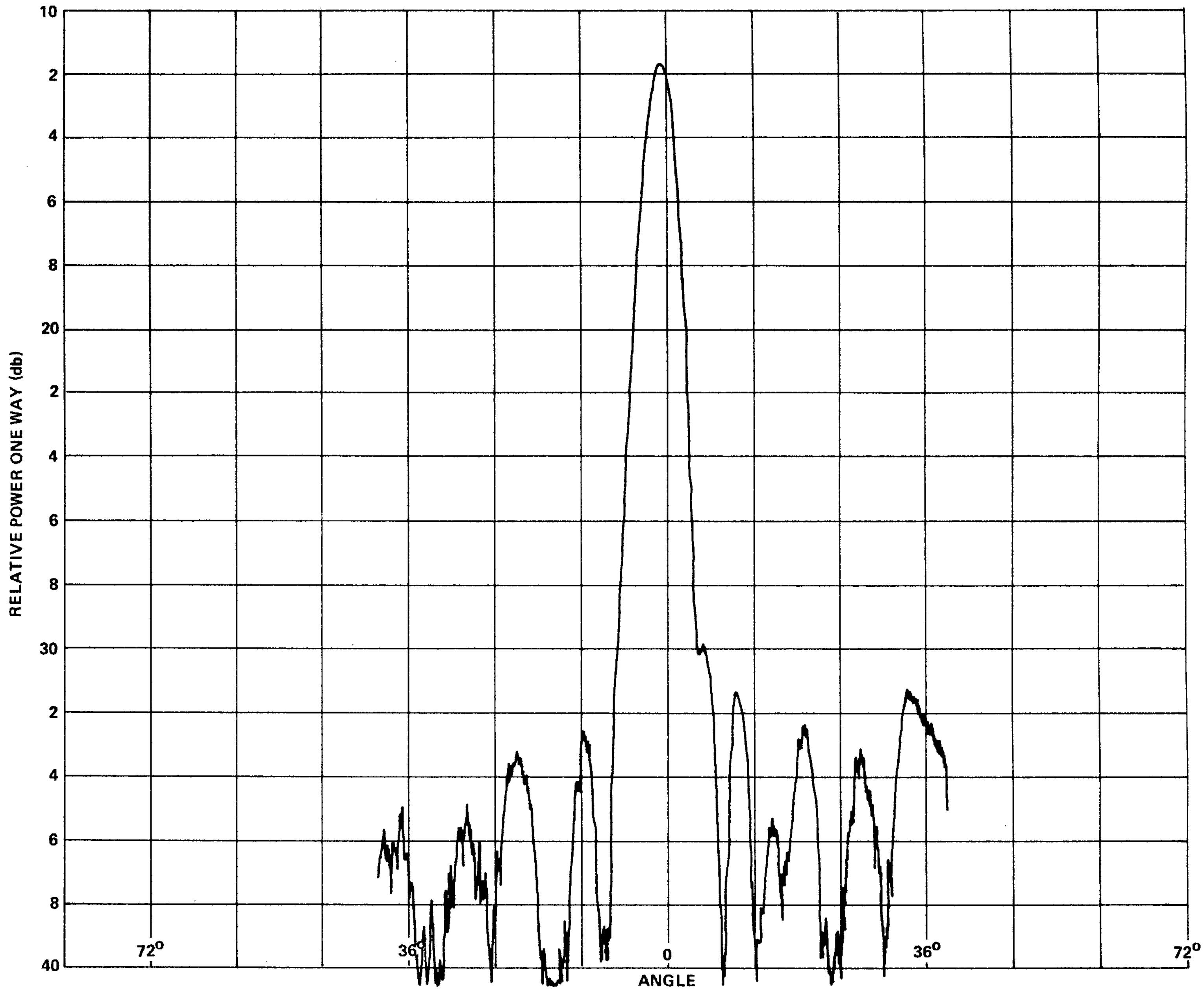

Figure 12. MMCA Antenna Test Pattern, Azimuth Plane, Horiztonal Polarization

Figures 13 and 14 antenna patterns are shown for the elevation plane with vertical and horizontal polarizations respectively. The 3-dB beamwidths can be seen from these patterns to be as follows:

- Azimuth Plane:

Vertical Polarization	5.0 degrees
Horizontal Polarization	4.5 degrees

- Elevation Plane:

Vertical Polarization	25 degrees
Horizontal Polarization	22 degrees

A fiberglass radome, $\lambda/2$ at the center frequency was fabricated and tested with the above antenna.

3.3 RECEIVER AND DETECTION ELECTRONICS

Referring to the block diagram of Figure 1, the IF output from the mixer is amplified before first detection in the AM detector. The IF transistor amplifier was purchased from Miteq, Inc. with the following characteristics:

• Frequency:	1.7 to 2.2 GHz
• Gain:	38 $\pm$ 0.5 dB
• Noise Figure:	5 dB maximum
• Output Power:	+10 dBm (at 1-dB compression)
• Input VSWR:	2.0:1 maximum
• Output VSWR:	2.0:1 maximum

The AM detector is a coaxial mounted Schottky barrier diode (Aertech DOM-1724BS). The output of the detector is a 1-kHz signal which drives an audio amplifier. The audio-amplifier first stage is a Precision Monolithics OP-07J low-noise operational amplifier. The second stage is a standard μA741 operational amplifier. The gain of the amplifier cascade is adjustable by a variable resistor at the output. A voltage gain of 10,000 is typically used.

The output of the audio amplifier is then fed to a Signetics SE567 PLL which is used as a synchronous detector. The internal oscillator of the SE567 is also used to drive an LM111 voltage comparator which supplies PIN modulator current. The output of the PLL is a 0 or 1 logic pulse that energizes the display electronics.

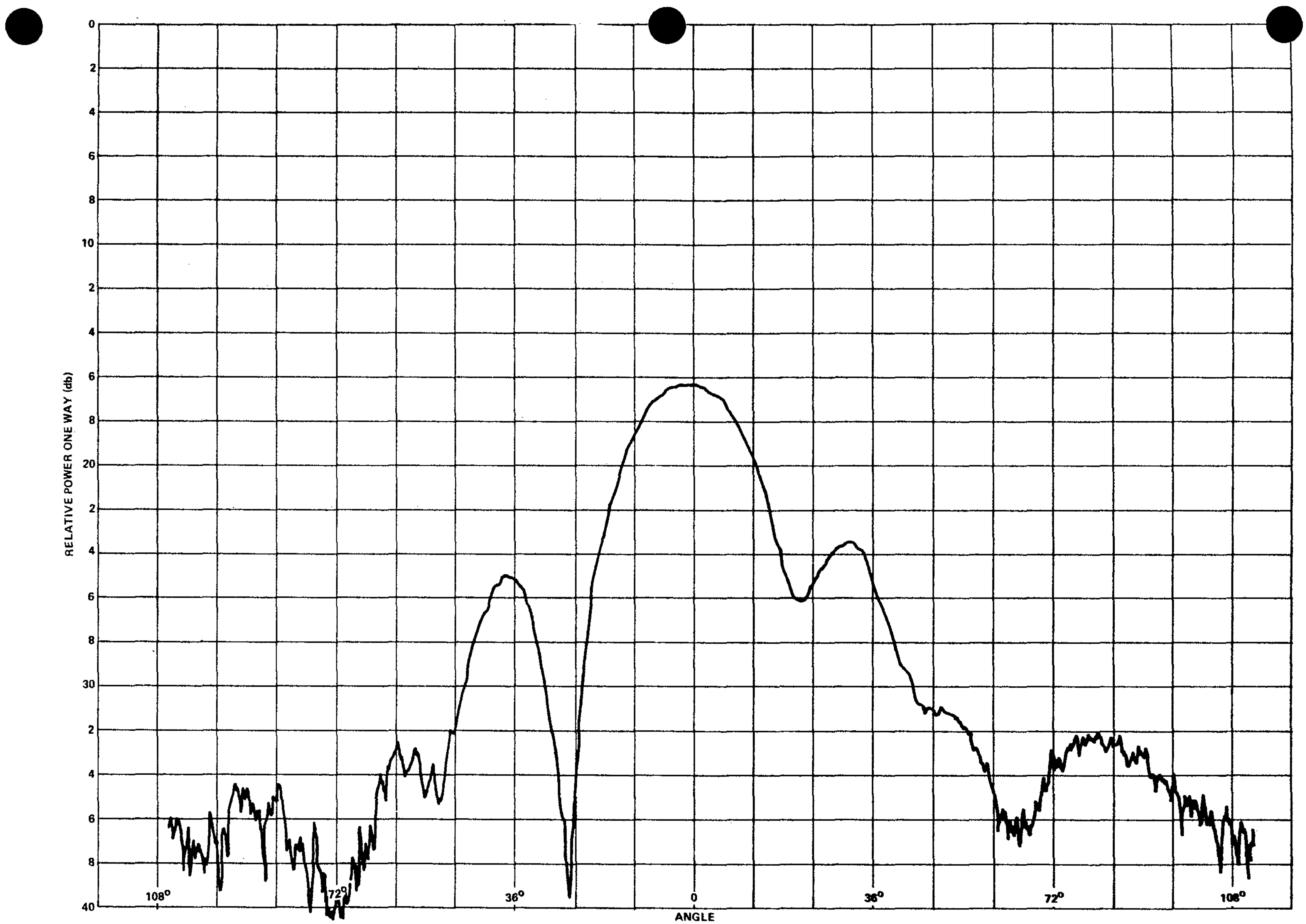

Figure 13. MMCA Antenna Test Pattern, Elevation Plane, Vertical Polarization

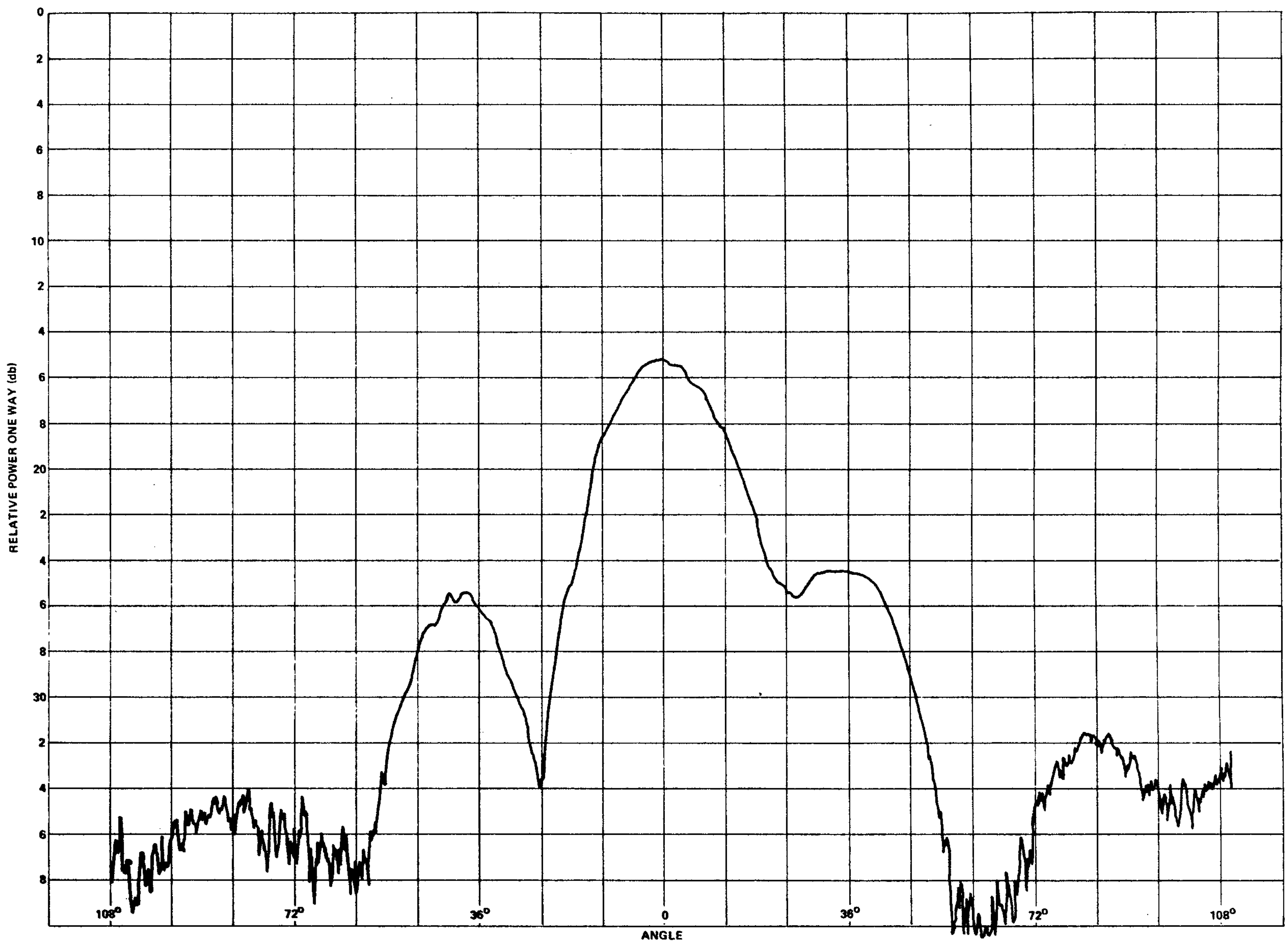

Figure 14. MMCA Antenna Test Pattern, Elevation Plane, Horizontal Polarization

Schematics of the audio amplifier and PLL circuits are contained in Appendix B.

3.4 DISPLAY ELECTRONICS

The display electronics consist of an array of 16 General Electric H13B2 photoisolators each providing the input to a 555 timer which drives an LED output. The photoisolator corresponding to the antenna position when an incoming RF signal is detected is selected by a shutter rotating in synchronization with the antenna shaft.

The photoisolators are mounted on a printed circuit (PC) board and are equally spaced around the antenna shaft. The timers are located on a PC board which is located in the power supply/ display housing. The 16 LED's, which provide visual signal bearing readout, are mounted on the front panel of the power supply/ display housing.

Schematic diagrams of the display PC boards and their interconnecting wiring are contained in Appendix B.

Section IV

PROTOTYPE SYSTEM

4.1 DESCRIPTION

The components whose designs were described in the preceding sections have been incorporated into an engineering model of the MMCA, millimeter-wavelength receiver system.

A photograph of the MMCA receiver assembly is shown in Figure 15. The remote CALL ALERT DISPLAY UNIT is shown in Figure 16. Figures 17 and 18 show the mast mounted receiver assembly with the radome removed. The mounting of the antenna and RF receiver components are shown in Figure 17. Details of the rotator as well as the IF and detection circuitry are shown in Figure 18.

Mechanically, the entire mast mounted assembly was built around the rotator and base assembly from the Raytheon 3100 radar. This unit was designed for use on small boats and has been tested extensively by the Coast Guard.

When assembled with its radome, the mast mounted receiver is weather resistant to withstand the rigors of the maritime environment. The mast mounted equipment occupies a volume of less than 1.5 cubic feet and weighs less than 27 pounds.

The CALL ALERT DISPLAY UNIT is also incorporated into a weather resistant housing. The volume of the display unit is approximately 1.3 cubic feet and its weight is less than 40 pounds.

Three MMCA receiver systems were fabricated and delivered to NRL for evaluation and sea trials. In addition, (125-foot)interconnecting cables were delivered with each system and a (50-foot) power input cable was supplied.

4.2 PERFORMANCE

The sensitivity of the three prototype MMCA receiver system was measured using the test setup whose block diagram is shown in Figure 19. A 22-foot test range was used so that both the trans-

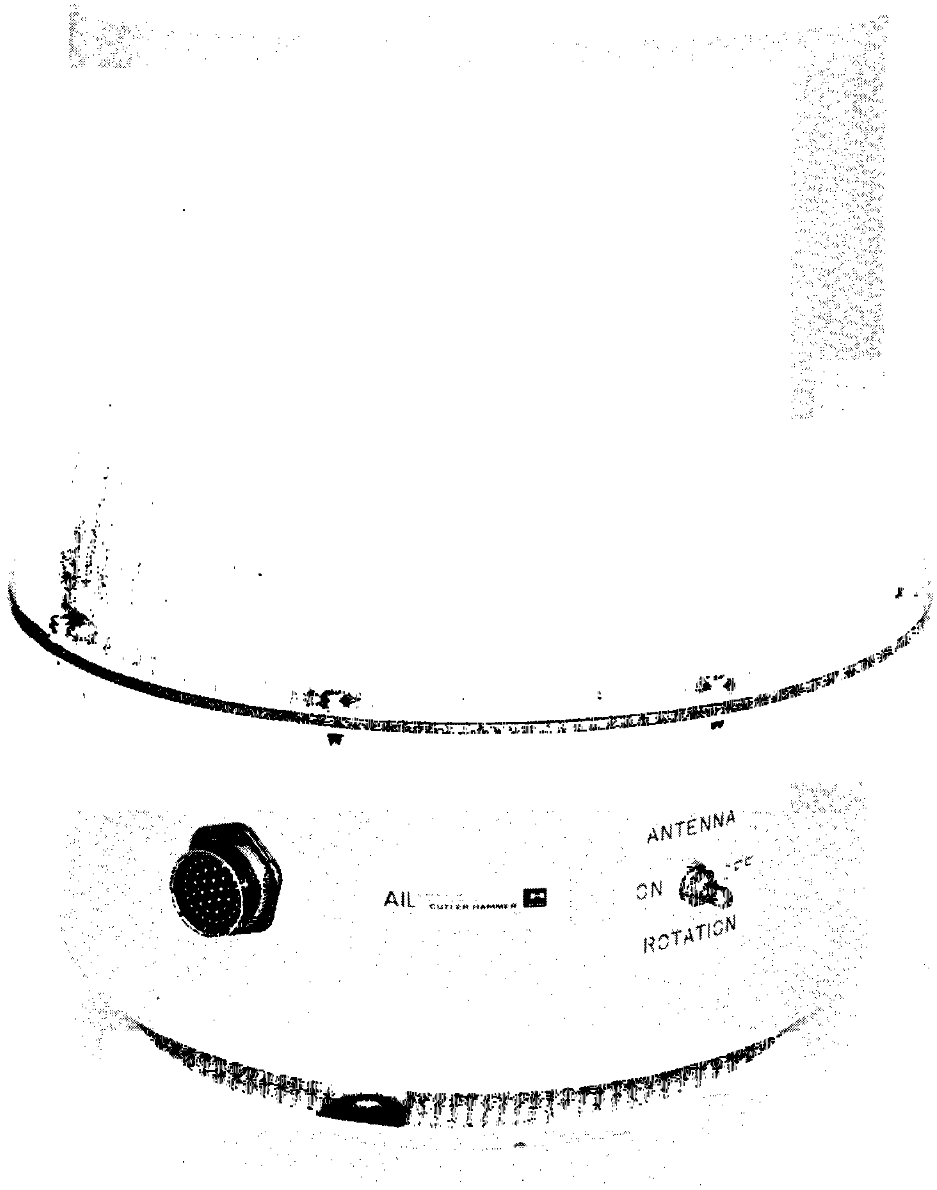

Figure 15. Prototype Mast Mounted Receiver Assembly

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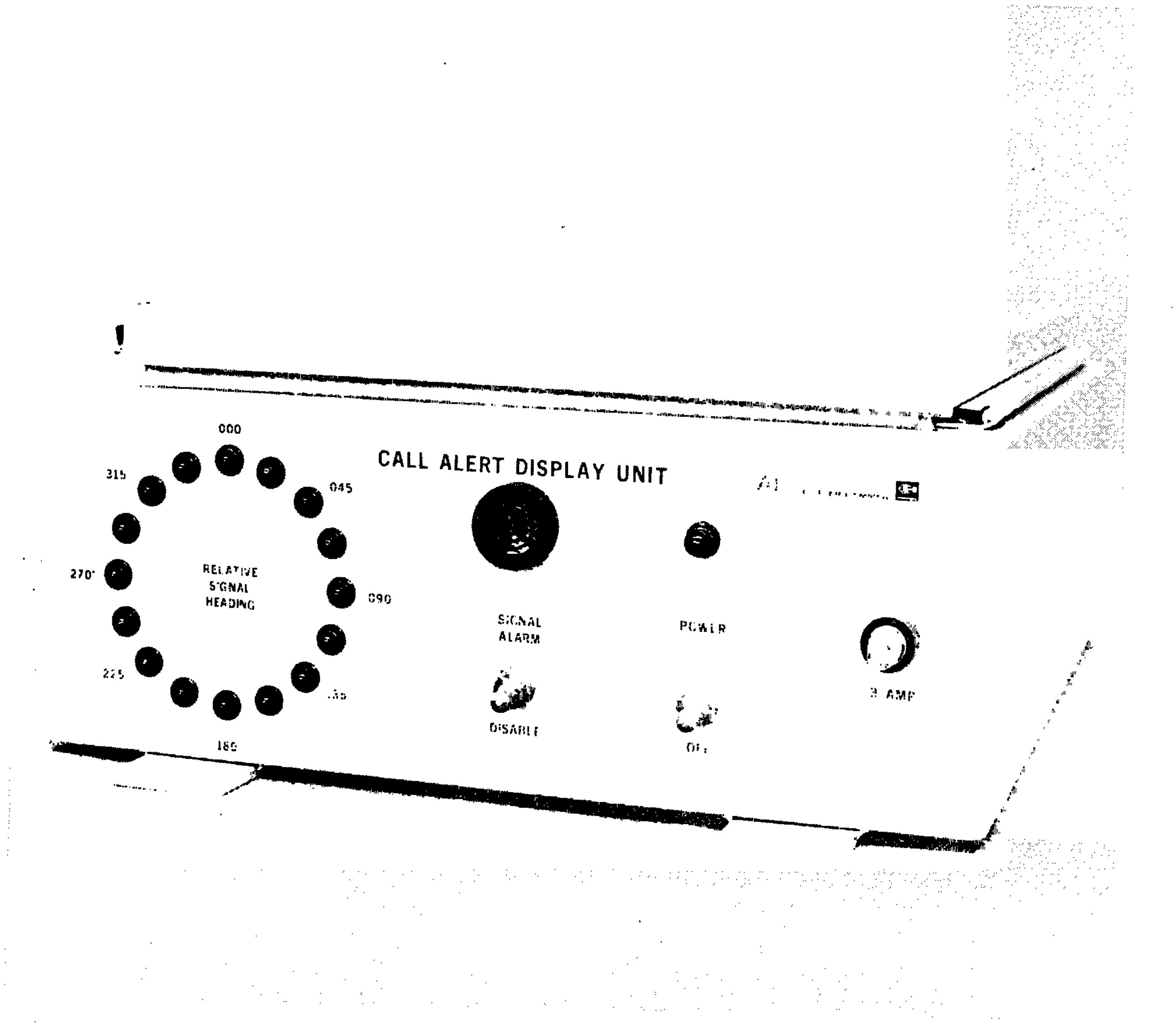

Figure 16. Prototype CALL ALERT DISPLAY UNIT

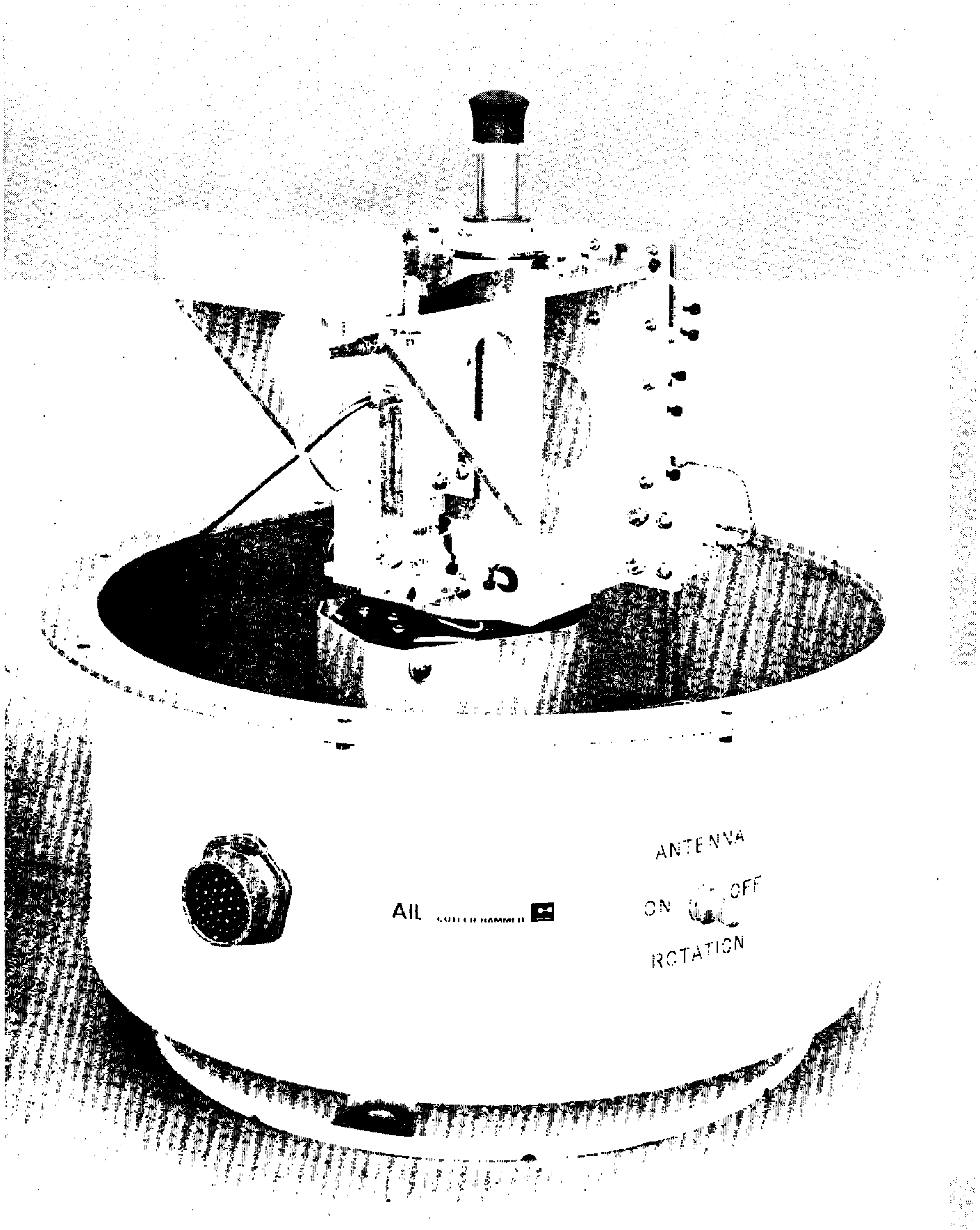

Figure 17. Antenna and Fin-Line RF Components Mounted in MMCA Receiver

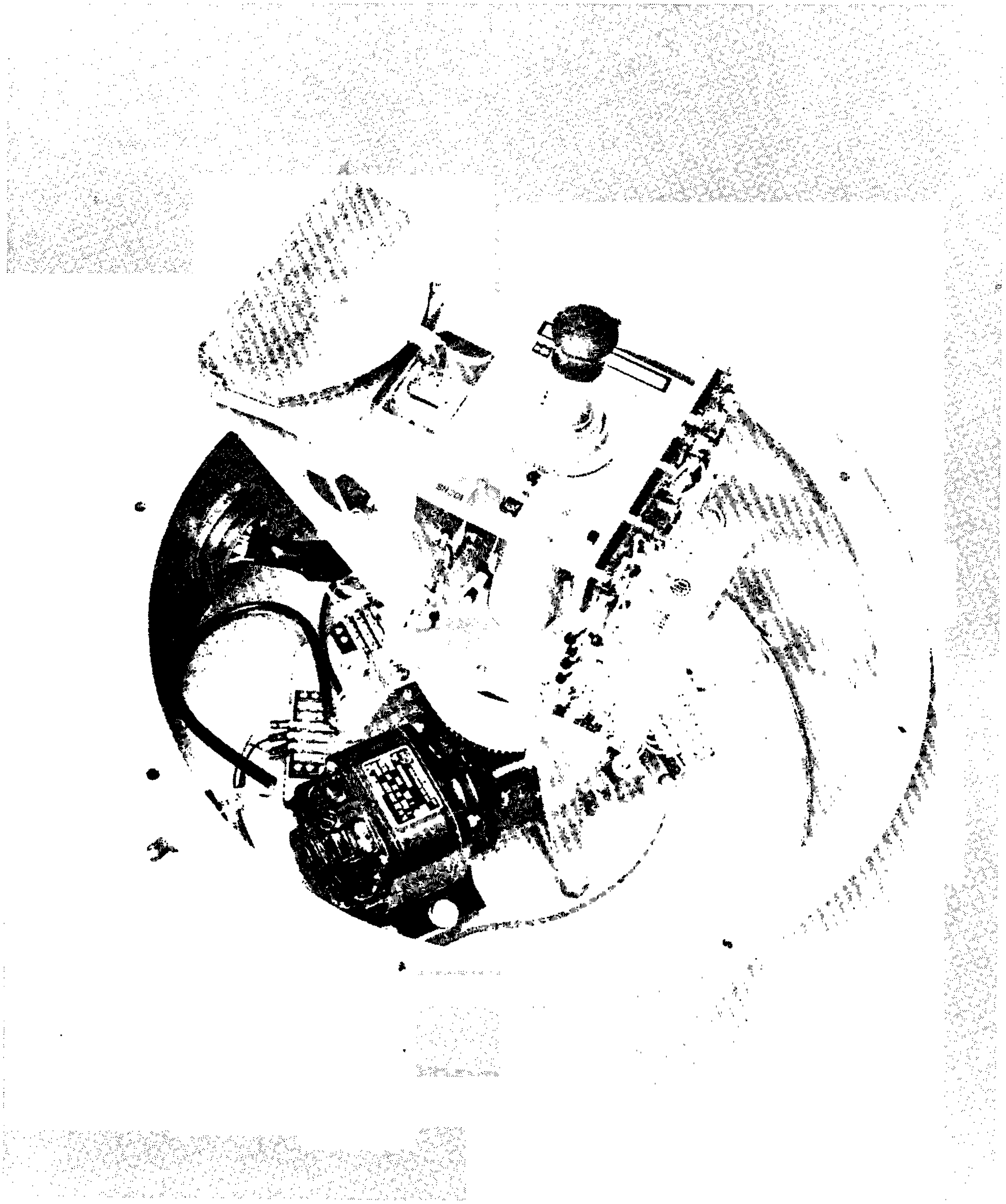

Figure 18. MMCA Receiver System Rotor and Electronics

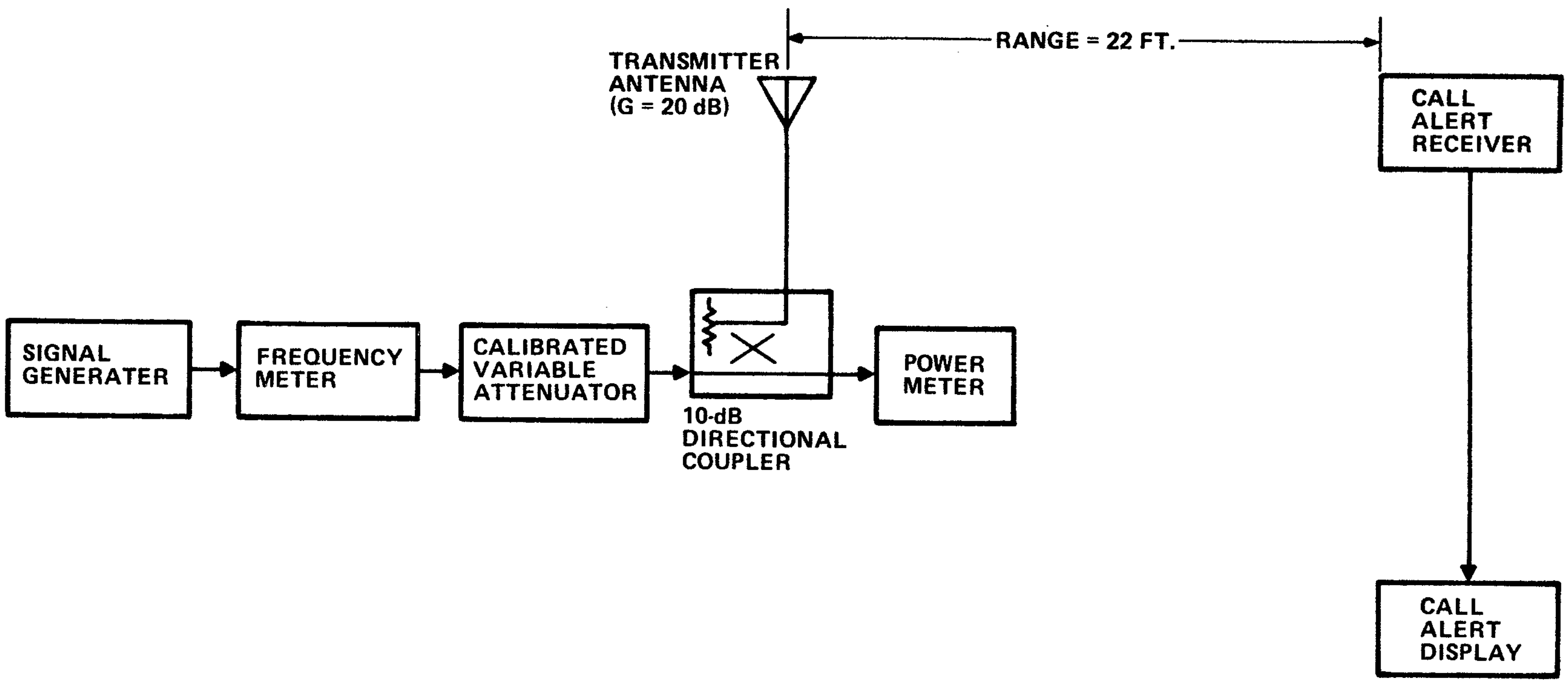

Figure 19. MMCA Receiver Sensitivity Measurement Setup

mitting and the receiving antenna would be operating in the far field region. The path loss for this distance was calculated from

$$L = \frac{\lambda^2}{(4\pi R)^2} = -80 \text{ dB}$$

The received power was calculated using

$$R_{REC} = P_t \; G_t \; G_R \; \frac{\lambda^2}{(4\pi R)^2}$$

where:

P_t = transmitter power
G_t = transmit antenna gain = 20 dB
G_R = receiver antenna gain = 21 dB

Thus a measurement of the transmitter power for threshold signal level of the receiver was reduced to the sensitivity in dBm at the fin-line receiver module input. The results of these measurements for the three systems is shown in Table III.

TABLE III
MMCA RECEIVER SENSITIVITY

System	P_{rec} (dBm)
001 Antenna Assembly Display Unit	-84
002 Antenna Assembly Display Unit	-86
003 Antenna Assembly Display Unit	-87

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4.3 PRODUCTION COST ESTIMATE

An estimate was made of the cost to manufacture 100 systems using the prototype configuration. The unit costs detailed below are based upon production of this quantity.

Fin-Line Receiver Module	$ 420
Gunn Diode Oscillator	530
Antenna	750
IF Amplifier	570
Rotator Mechanism and Base	1,020
Receiver Electronics	2,400
Mast Mounted Receiver Assembly Total	$ 5,690
Display Unit Assembly	2,690
Cables	520
Total System Cost	$ 8,900

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Section V

CONCLUSION

This report has described the design and development of a millimeter-wavelength mast mounted CALL ALERT receiver system. This system is designed to sense the presence of an incoming K_a-band signal over a range in excess of 10 nm, and to provide an audio alarm and a visual indication of the direction of the received signal.

Three prototype MMCA systems were constructed to demonstrate the feasibility of this design. The performance of the prototype systems met the design goals which were established for electrical performance. In addition, the mechanical design of the MMCA was configured so that the prototype systems would be suitable for evaluation in a shipboard environment.

A reasonable cost is projected for the quantity production of the MMCA system due to the use of AIL's patented fin-line transmission techniques. Suggestions for future development include:

- Upgrading the prototype system design to meet full military specifications
- Modifying the receiver design and incorporating transmitter components to result in a complete communications transceiver

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REFERENCES

1. P.J. Meier, "Two New Integrated-Circuit Media With Special Advantages at Millimeter Wavelengths," IEEE 1972 G-MTT Symposium Digest, pp 221-223, May 1972.

2. D. Dobramysl, "Integrated Mixers for 18 and 26 GHz," IEEE 1971 G-MTT Symposium Digest, pp 18-19, May 1971.

3. T.H. Oxley, et al, "Hybrid Microwave Integrated Circuits for Millimeter Wavelengths," IEEE 1972 G-MTT Symposium Digest, pp 224-226, May 1972.

4. J.J. Taub, "The Status of Quasi-Optical Waveguide Components for Millimeter and Submillimeter Wavelengths," Microwave Journal, pp 57-62, November 1970.

5. P.J. Meier, "Equivalent Relative Permittivity and Unloaded Q Factor of Integrated Fin-Line," Electronic Letters (Brit. IEE), Vol. 9, No. 7, pp 162-163, April 1973.

6. P.J. Meier, "Microwave Transmission Line," U.S. Patent No. 3, 825, 863; July 1974.

7. S.B. Cohn, "Properties of Ridged Waveguide," Proc. IRE, Vol. 35, pp 783-788, August 1947.

8. S. Hopfer, "The Design of Ridged Waveguides," IRE Trans, MTT-3, pp 20-29, October 1955.

9. F.E. Gardiol, "Higher-Order Modes in Dielectrically Loaded Rectangular Waveguides," IEEE Trans. MTT-16, pp 919-924, November 1968.

10. P.H. Vartanian, W.P. Ayres, and A.L. Helgesson, "Propagation in Dielectric Slab Loaded Rectangular Waveguide," IRE Trans. MTT-6, pp 215-222, April 1958.

11. P.J. Meier, "Integrated Fin-Line Millimeter Components," IEEE Trans, MTT-22, pp 1209-1216, December 1974.

12. P.J. Meier, "New Developments With Integrated Fin-Line and Related Printed Millimeter Circuits," IEEE 1975 G-MTT Symposium Digest, May 1975.

APPENDIX A

OPERATION AND MAINTENANCE

1.0 INTRODUCTION

This appendix presents the operating and maintenance instructions for the AIL MMCA millimeter-wave receiving system. The MMCA receiver consists of the following parts:

- o Mast Mounted Receiver Assembly P/N 555296-1
- o CALL ALERT DISPLAY UNIT P/N 555298-1
- o Interconnecting Cable (125 feet)
- o Power Input Cable (50 feet)

2.0 OPERATION

2.1 INITIAL TURN-ON

The procedure for initial setup and turn-on of the MMCA receiver is as follows:

a. Interconnect the Mast Mounted Receiver Assembly and the CALL ALERT DISPLAY UNIT using the 125-foot cable which is supplied.

b. Verify that the antenna rotation switch on the receiver assembly is in the on position.

c. With the power switch in the off position, connect the power input cable to connector J1 on the Display Unit. The connections for the power input cable are as follows:

Pin	Connection	Wire	
A	115 Vac hot	No. 18	Twisted pair
B	AC common	No. 18	
C	Ground	Shield	

d. Turn on power switch. The receiver is now operational. (Note: Spurious signal indications may occur for the first five minutes of system operation. This is normal and does not require adjustment.)

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e. In normal operation, when a K_a-band signal is present, the display lamp corresponding to the direction of origin of the received signal will flash at two-second intervals. In addition, an audio alarm will sound to call attention to the signal presence. If desired the signal alarm switch may be set in the disable position and the audio tone will not sound.

2.2 SYSTEM GAIN ADJUSTMENT

This adjustment has been set and locked at AIL and should not require readjustment. However, should it be desired to reset the sensitivity of the system, a fine adjustment of system gain can be made as follows:

a. With system off disassemble the radome from the base by removing mounting screws.

b. To increase sensitivity approximately 2 dB turn the adjusting screw on variable resistor R2 one turn counterclockwise. To decrease sensitivity approximately 2 dB turn the adjusting screw on variable resistor R2 one turn clockwise. (Note: If more adjustment than this is required return system to AIL for recalibration.)

c. Reinstall radome and turn on system to verify proper operation.

3.0 MAINTENANCE

The only periodic maintenance required is annual lubrication of the shaft bearings and the drive mechanism. Access to these areas is obtained by disassembly of the radome from its base by removing the mounting screws.

CAUTION

Use Mobil Almo 2 oil only.

Place six drops of oil on the lubricating roller assembly that contacts the shaft roller gear. Also place three drops of oil on the shaft at the upper bearing collar and let the oil run into the bearing. Wipe excess oil off the shaft. Replace radome.

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APPENDIX B

SCHEMATIC DIAGRAMS

For reference the following schematic diagrams are presented in this appendix.

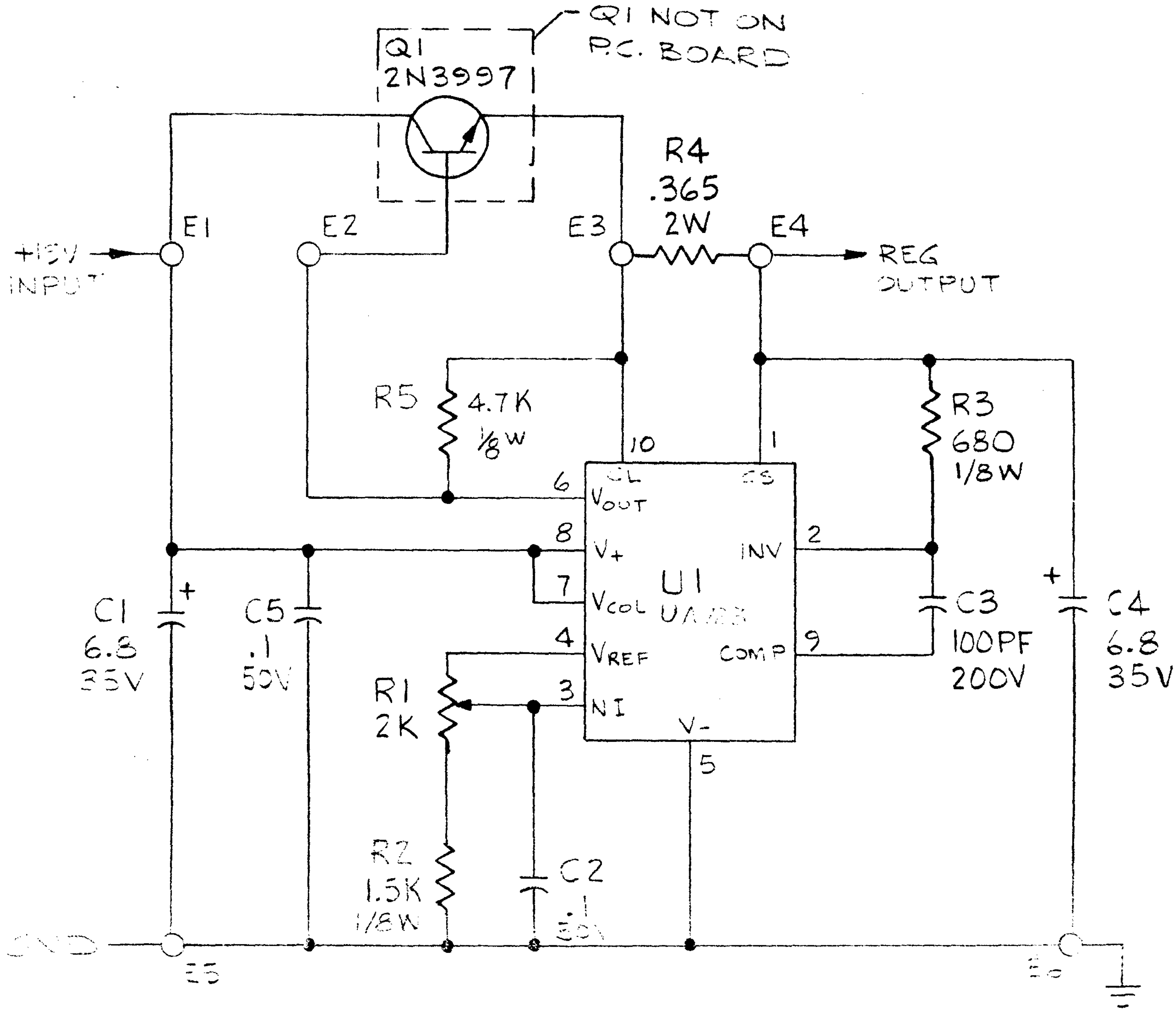


Figure B-1. GDO Regulator Schematic

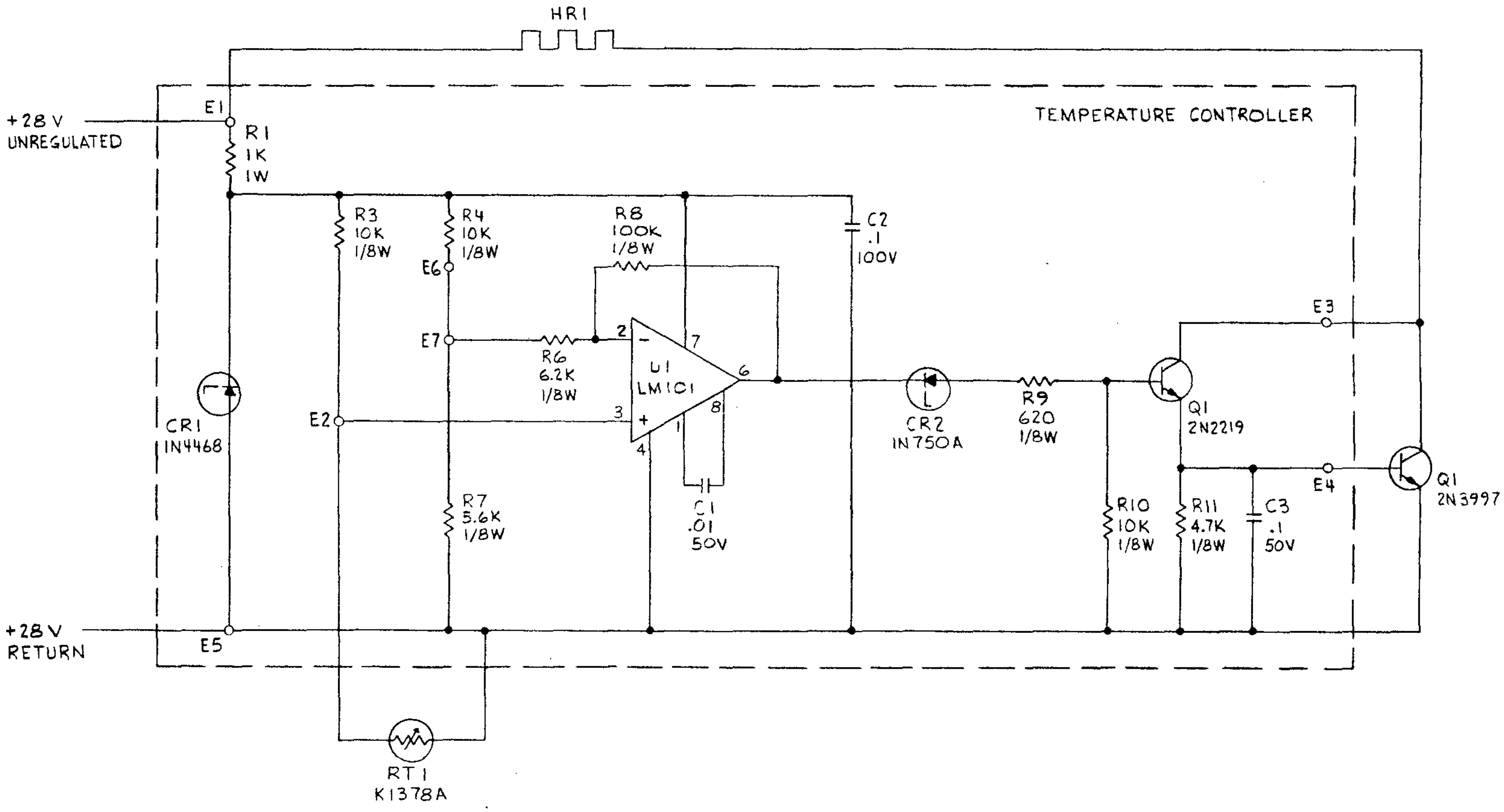
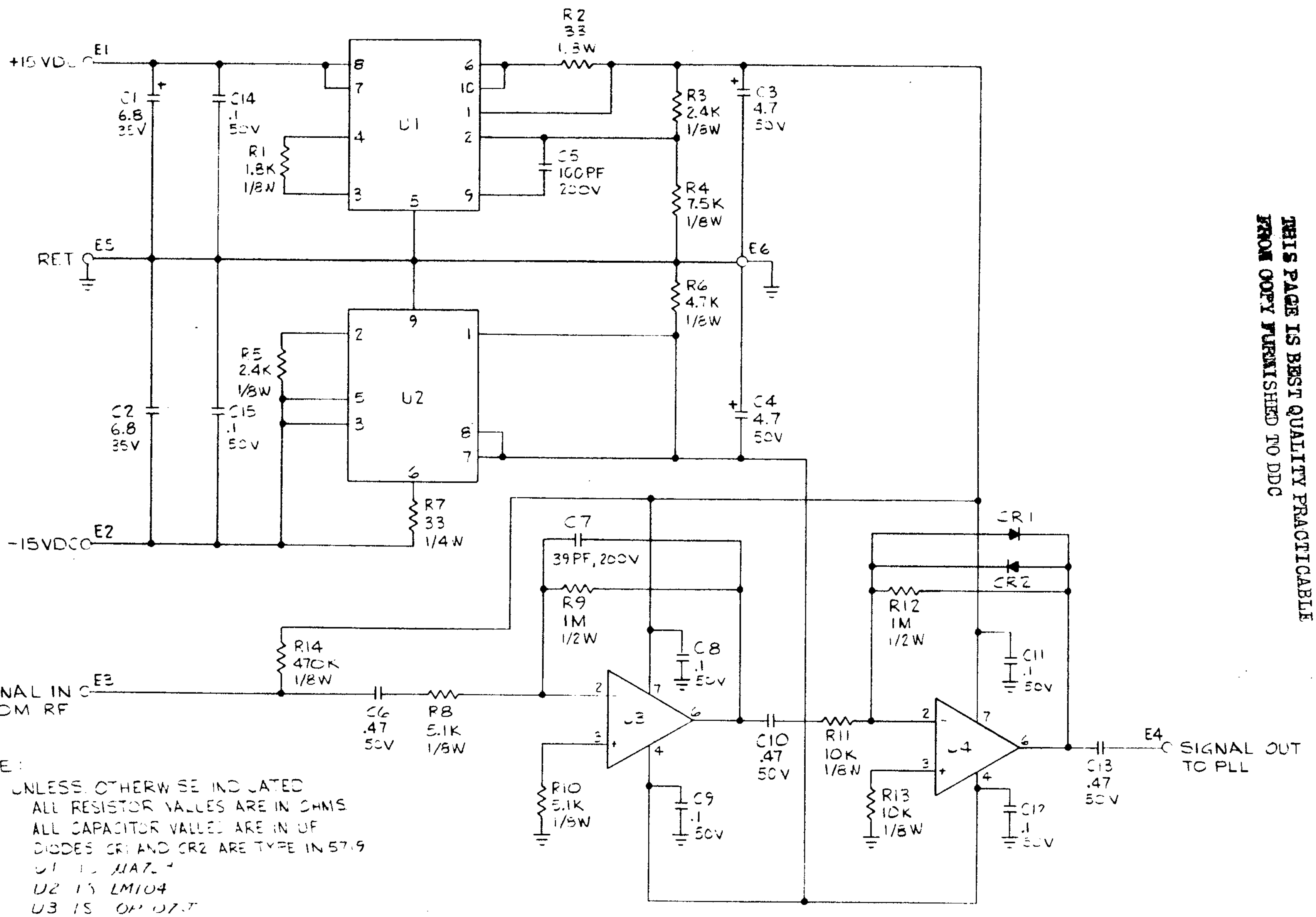


Figure B-2. Temperature Controller Schematic



NOTE:

1. UNLESS OTHERWISE INDICATED
   ALL RESISTOR VALUES ARE IN OHMS
   ALL CAPACITOR VALUES ARE IN UF
   DIODES CR1 AND CR2 ARE TYPE IN 5719
   U1 IS UA72
   U2 IS LM104
   U3 IS OP 07
   U4 IS UA741

Figure B-3. Audio Amplifier Schematic

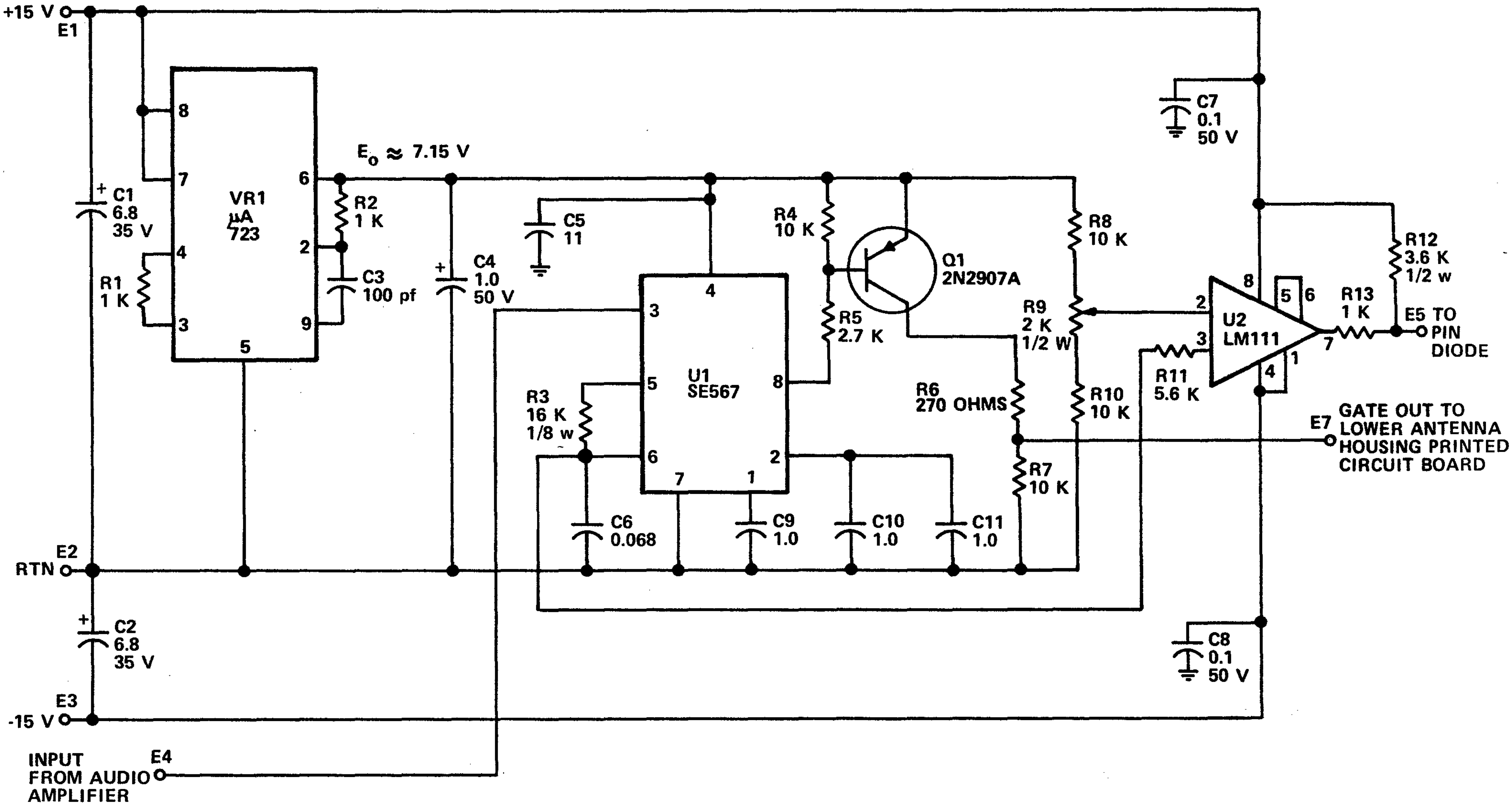


Figure B-4. Phase Locked Loop and PIN Diode Driver Schematic

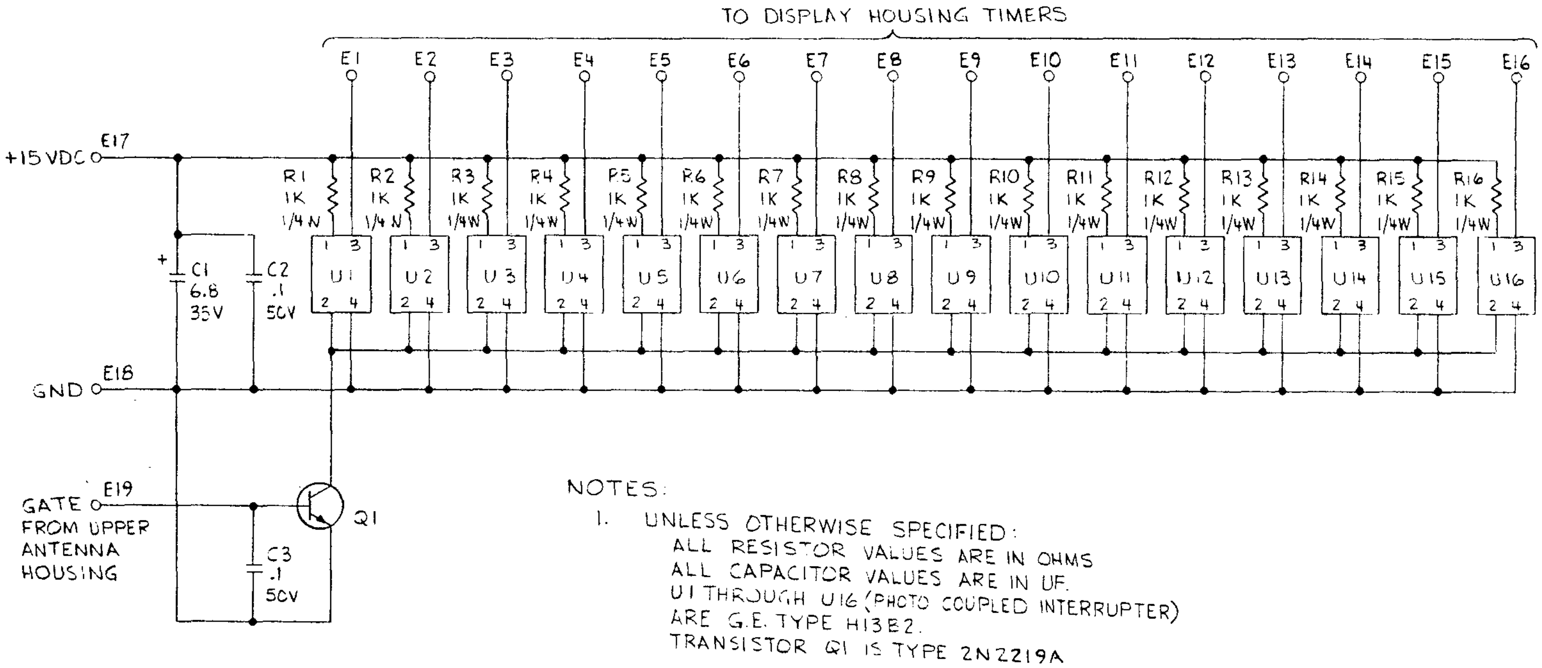


Figure B-5. Shaft Encoder Schematic

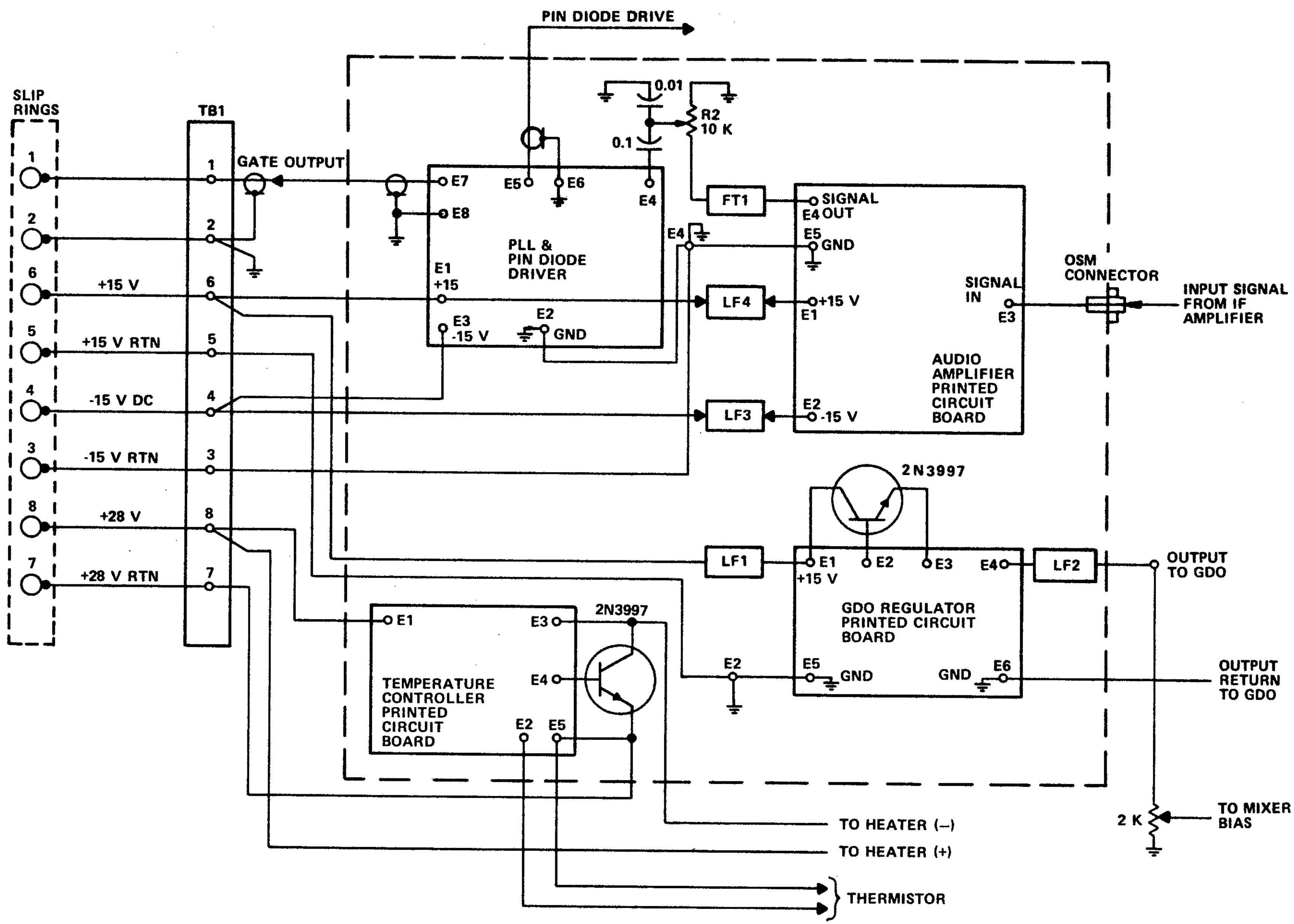


Figure B-6. Upper Antenna Housing Schematic

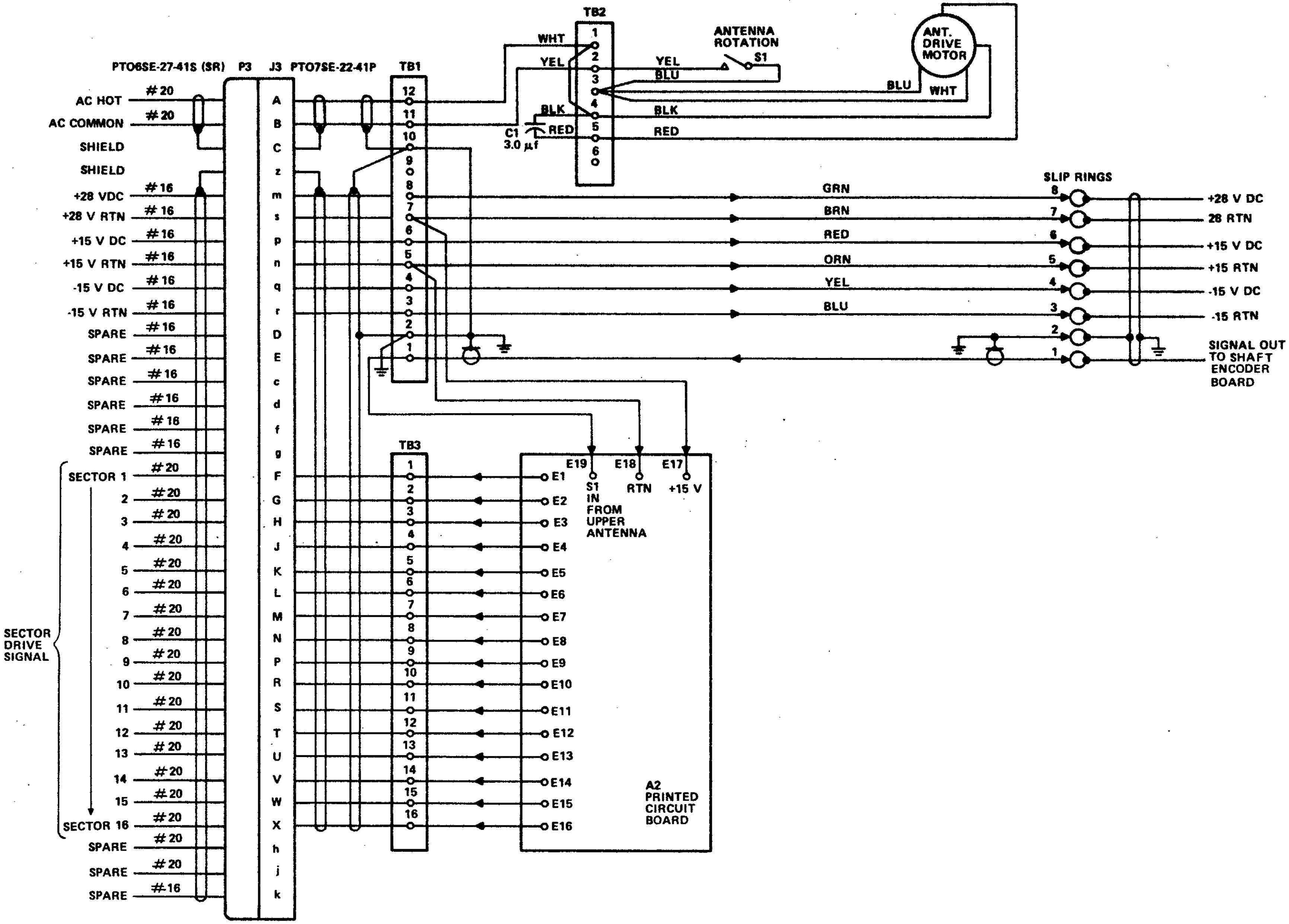


Figure B-7. Lower Antenna Housing Schematic

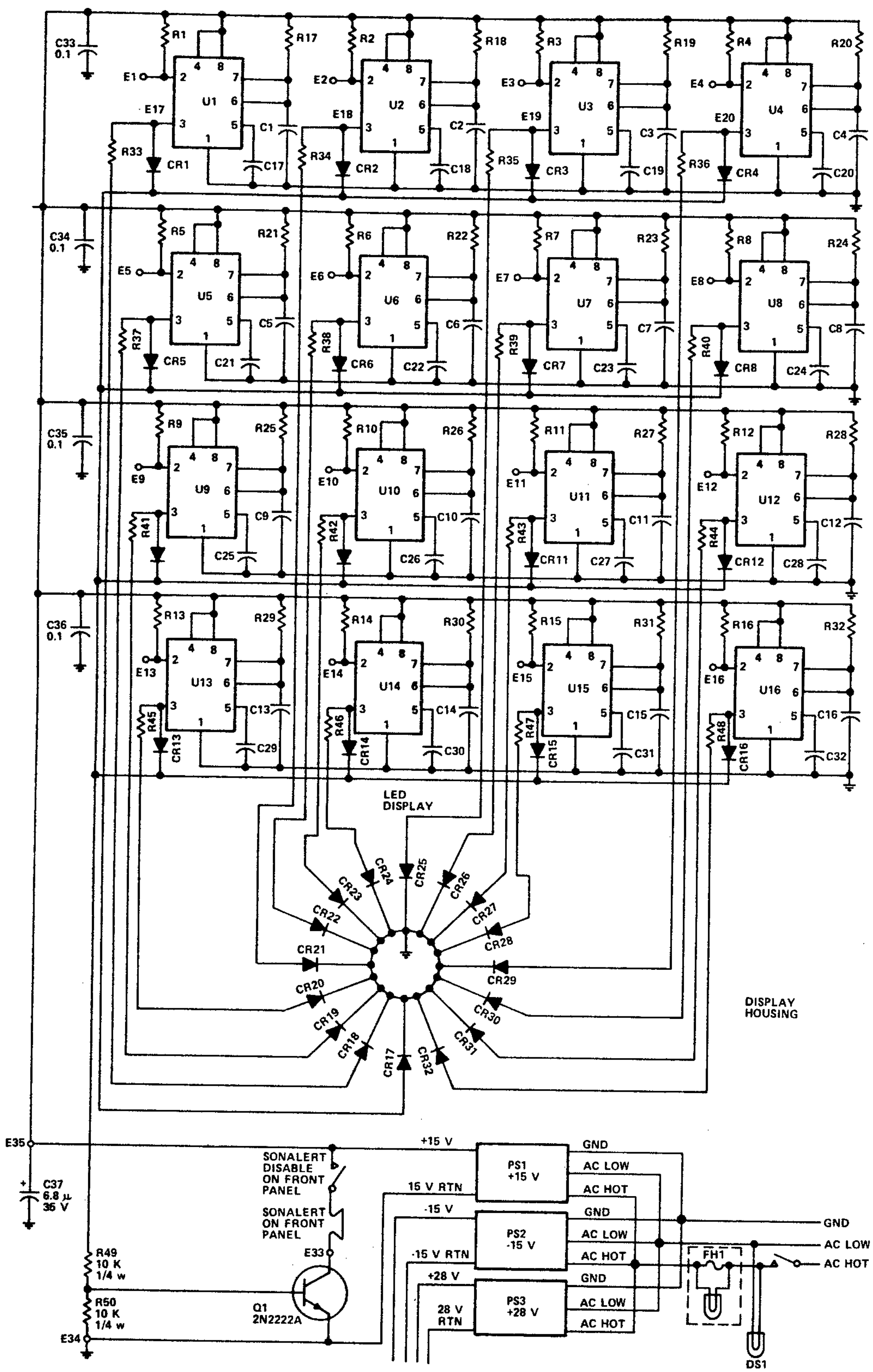


Figure B-8. Display Unit Schematic Diagram